ILLUMINATING ENGINEERING

JANUARY 1954

In Two Sections — Section 1

◆

Mercury Lamp Starting in Outdoor Applications
Dimming Hot Cathode Fluorescent Lamps
Analysis of Comfort and Glare
Continuous Daylight Recorder
Multichromatic Colorimeter
The Orientation Reflex
Church Lighting

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

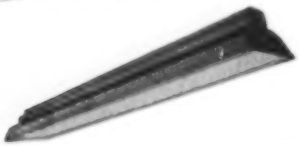
lighting problems SOLVED

for every plant location with a specific Benjamin Unit

THIS CHECK CHART OF BENJAMIN LIGHTING UNITS

shows how lighting can be matched to every seeing task in the plant!

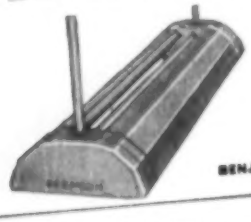
☐ **1.** fluorescent lighting of **GENERAL PLANT AREAS**



Over 300 combinations for matched-to-the-task lighting. Just three channel sizes and four types of reflectors form the backbone of an almost unlimited number of lighting systems for general industrial seeing tasks. Features utilization of high-light-output T12 Slimline lamps and exclusive "Springlox" Lampholders for lower maintenance cost through quicker lamp servicing.

BENJAMIN "Magna-Flo" Systems *described in Manual #1*

☐ **2.** fluorescent lighting to overcome **EXCESSIVE BRIGHTNESS RATIOS**



A new high in seeing comfort for industry! "Task-Master" combines greater upward flow of light with a new high of 35° lamp shielding. Revolutionary new, easier methods of installation and maintenance keep operating and maintenance costs at an all-time low.

BENJAMIN "Task-Master" *described in Manual #2*

☐ **3.** lighting of **HIGH BAYS**

A rugged lighting unit for steel mills, foundries, sheet metal works, and other locations where the lighting units must be guarded against damage from rough handling, flying metal particles, severe mechanical strain or unfavorable atmospheric conditions.

BENJAMIN "Steelite" *described in Manual #3*

☐ **4.** incandescent lighting of **GENERAL PLANT AREAS**

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BENJAMIN "Turnlox" Dome Reflector *described in Manual #4*

☐ **5.** lighting for **BINS and SHELVES**

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☐ **6.** safe lighting for **HAZARDOUS LOCATIONS**

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☐ **8.** proper floodlighting for **OUTDOOR INDUSTRIAL AREAS**

The ideal all-weather unit for industrial recreational areas, ball fields, pools, etc. Highest quality outdoor illumination due to combination of large diffusing Porcelain-Enameled Steel Reflector with inner aluminum reflector.

BENJAMIN "Play Area" Floodlight *described in Manual #8*

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- ☐ 7. Humid Locations
- ☐ 8. Industrial Floodlighting

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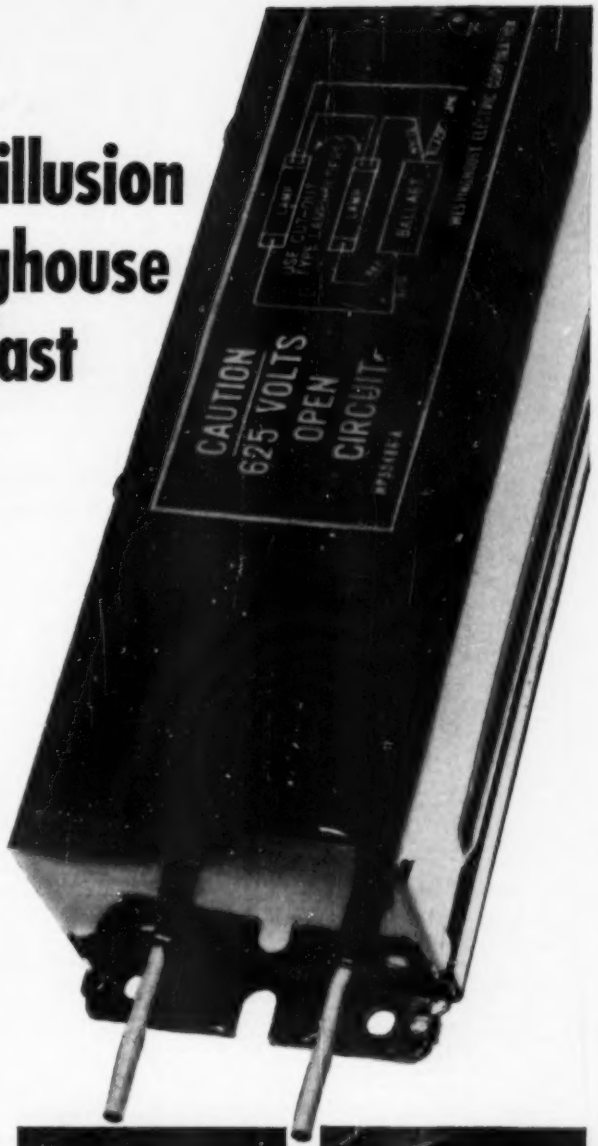

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3. Low installation costs, because of simple wiring, light weight and small sizes in the *new* Westinghouse *lead-lag* ballast.
4. Minimum heat to be dissipated by the fixture, because of the reduced wattage loss in the new Westinghouse design.

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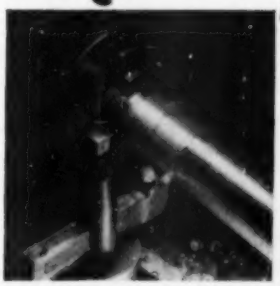

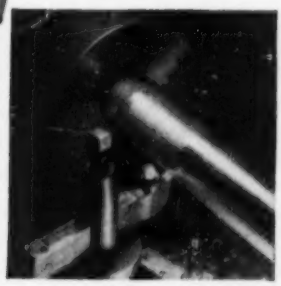

In left-hand photo, the lathe is purposely stopped to demonstrate the dangerous illusion that can result under conditions where series ballasts are in use. *In right-hand photo,* the lathe is in operation, an apparent fact when the light source incorporates a *lead-lag* ballast.

YOU CAN BE **SURE**...IF IT'S

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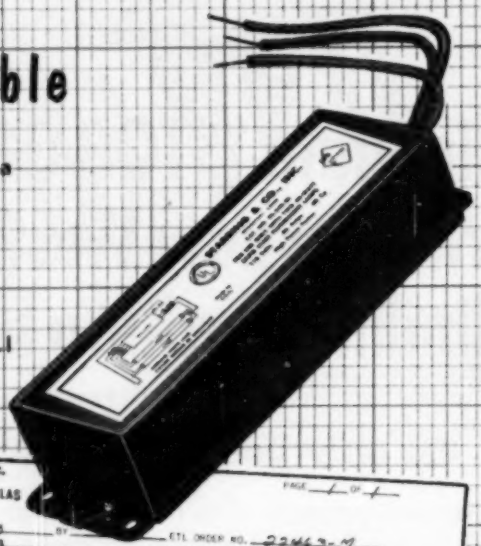
Check these Electrical Testing Laboratories' Data
on the Starring

RS240SR

Rapid-Start Ballast

against Supplement 2 to Proposed ASA Specification C82.1



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TESTS OF FLUORESCENT LAMP BALLAST

Rapid Start

MFR. STARRING Co., Inc. — PLANT Bridgeport Conn.

CAT. NO. RS240-SR FOR 2 LAMPS

RATING: Watts 40 volts 118 ma. 435 cycles 60

DATE SELECTED 9/23/53 BY

DATE RECEIVED 9/24/53 ETL ORDER NO. 22463-M

DATE TESTED 9/30/53 10/29/53 TESTED BY A.T.C. MFR'S ORDER NO. —

DATA APPROVED HMC

PAGE 1 OF 1

ETL SAMPLE NO.	CIRCUIT	SUPPLY VOLTAGE, VOLTS	VOLTAGE BETWEEN LAMP TERMINALS: RMS VOLTS	VOLTAGE BETWEEN LAMP TERMINALS: PEAK VOLTS	VOLTAGE BETWEEN LAMP TERMINALS: CREST FACTOR	LAMP TERMINAL TO STARTING AID*: RMS VOLTS	LAMP TERMINAL TO STARTING AID*: CURRENT TO GND MA	INPUT TO REFERENCE LAMPS: VOLTAGE VOLTS	INPUT TO REFERENCE LAMPS: RMS CURRENT, AMP	INPUT TO REFERENCE LAMPS: POWER WATTS	INPUT TO REFERENCE LAMPS: PEAK CURRENT AMP	INPUT TO REFERENCE LAMPS: CREST FACTOR	OVERALL POWER FACTOR PER CENT	LIGHT OUTPUT	CATHODE HEATING VOLTAGE, VOLTS: CURRENT LOAD	CATHODE HEATING VOLTAGE, VOLTS: CURRENT NO LOAD	STARTING CAPACITOR, MFD	HEATING TEST: OBJECT TEMP C	HEATING TEST: COIL RESISTANCE, OHMS	UNDECODED TEMP C
9-182	Blue	105	860																		
		118	981	4.25		162	—														
		130																			
	Red	105							0.415	—	1.60	1.57	—		127	3.50	3.50	0.41			
		118													137						
		130							0.417	—	1.650	1.56	—		143						
	Yellow	118													146	3.48	3.48				
	Violet	11													151						
9-183	Blue	105	254													3.50	3.56				
		118	282	4.25		160	—		0.820	24.9	—	—	—	98.0	—						
		130													130						
	Red	105							0.405	—	1.65	1.52	—		148	3.60	3.52	.041			
		118													165						
		130													124						
	Yellow	118							0.418	—	0.780	1.48	—		143	3.56	3.64				
	Violet	11													147						
9-184	Blue	105	257													3.50	3.60				
		118	284	4.40		164	—		0.804	23.1	—	—	—	98.2	—						
		130													134						
	Red	105							0.413	—	0.600	1.50	—		150	3.48	3.52	.042			
		118													125						
		130							0.408	—	0.600	1.52	—		129						
	Yellow	118													144	3.46	3.50				
	Violet	11													151						
9-185	Blue	105	284						0.820	25.9	—	—	—	99.2	—	3.50	3.70				
		118	317	4.25		182	—														
		130							0.407	—	0.610	1.50	—		133						
	Red	105													149	3.50	3.52	.040			
		118													156						
		130							0.407	—	0.610	1.50	—		126						
	Yellow	118													144	3.50	3.62				
	Violet	11													150						
9-186	Blue	105	278						0.819	25.9	—	—	—	98.4	—	3.54	3.60				
		118	284	4.25		163	—														
		130							0.410	—	0.630	1.54	—		134						
	Red	105													149	3.62	3.60	.042			
		118													161						
		130													130						
	Yellow	118							0.418	—	0.640	1.55	—		144	3.62	3.70				
	Violet	11													152						
									0.811	24.9	—	—	—	98.0	—	3.60	3.64	—			

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RS240SR

9½" x 2¾" x 2 1/16"
Mounting Length, 8⅞"
Weight 6 pounds

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ILLUMINATING ENGINEERING

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

JANUARY 1954

Vol. XLIX
No. 1

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Founded 1906

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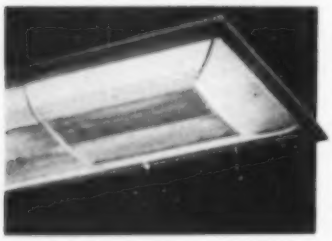
INSTALLATION: Accounting Office, Conn. Light & Power Co., New Britain, Conn.
DESIGNER: S. S. Webster (Conn. Light & Power Co.)
ENGINEER: T. J. Clare (Conn. Light & Power Co.)
AREA: 40' x 60'
CEILING HEIGHT: 10'
SPACING: 7' on centers
FIXTURES: No. 4828, 2-lamp, 96" recessed troffers, with hinged doors and Holophane No. 9033 and No. 9034 low-brightness lenses
LAMPS: Standard Cool White
AVERAGE INTENSITY IN SERVICE: 100 footcandles

HOW BRIGHT

is this Glare-Free LITECONTROL Installation?

Architects, contractors and owners work with LITECONTROL engineers to make every job a custom installation. In this case, almost twice as much light as usual was wanted; yet it had to be glare-free, easy on accountants' and bookkeepers' eyes all day long. LITECONTROL did the job: the room is filled with light and there's practically no glare, although the average intensity is 100 footcandles.



LITECONTROL 4828 recessed troffers with Holophane low-brightness lenses are used. The lenses reduce glare to a minimum, even when you look right at the fixtures. And the convex design throws plenty of light against the ceiling: fixture-ceiling contrast is minimized and the softer reflected light is added to the direct light from the fixtures.

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TAKING STOCK—

On An Anniversary

ILLUMINATING ENGINEERING in its present format is five years old today. Perhaps five years isn't enough to give even a magazine a "past"—but it's a good place nevertheless, to take stock.

THE GOAL of the "new IE," when it was inaugurated January 1949, was, to quote the opening editorial, "a new and broader publication service to the entire lighting field." This was, in fact, part of a pattern pieced together over the years—a plan aimed continuously toward a publication of more and more practical usefulness to more and more readers.

THE NEW enlarged IE was not the first step in this plan. Older members will remember their pleased surprise when they first saw the January 1940 issue. With a new name, and a progressive editorial policy, the Society's "Transactions" in that year became ILLUMINATING ENGINEERING, and took a constructive step forward. The introductory editorial in that issue outlined its hope "to devote more space to applied engineering as well as to pure engineering, and to lay a foundation for a more usable publication." It was, indeed, more usable to more members.

EVEN SO, with the war effort successfully over in 1945, the Society again studied its publication program. The committee appointed to this task planned for a very greatly expanded publication. One that would retain all the valuable reference material of the old journal, and publish as well, timely material on current lighting practice. The whole program expanded—in size, in format, scope and policy. Just five years ago today.

HOW'RE we doing after five years? More people like us, that we know. We're recognized as the top-flight magazine in the lighting field, as well as *the* reference journal for illuminating engineering. Thousands of our reprints are demanded as soon as they're published.

DO WE really publish lots of timely articles showing how to apply our own Recommended Practices? Last year 51 per cent of all titles in ILLUMINATING ENGINEERING were "how-to" articles on good current lighting technique.

HAVE WE sacrificed the technical excellence of our journal to do this? Seems not! By page volume, 54 per cent of the pages published last year was transactions of I.E.S. and other technical papers on research, development and engineering. And we publish more pages, and bigger pages than the "old IE," and twelve issues instead of ten.

HOW ABOUT educational material? Some of our readers want to absorb engineering practices in as painless a form as possible. Good. That's why the Questions and Answers page was developed by the Light Sources Committee. And the "characteristics of materials" series were sought and published. In this series so far, articles have been presented on the characteristics of plastics, porcelain enamel, 300° white baked enamel, Alzak aluminum, acoustical materials, tungsten, and the Underwriter's operation. Coming up are the characteristics of quartz, mercury, phosphors and glass.

IF THE "new" publication, now five years old, is approaching its goal of "service to the entire lighting industry," then the I.E.S. membership itself should take the credit. They are its authors, as well as its readers. More and more members in all phases—technical, theory and application—have taken pen in hand to share on paper, their own experiences in lighting practice and technical development. Still more are herewith invited, nay urged, to participate in the program of this, their own publication.

A Continuous Daylight Recorder

By W. H. BILLHARTZ
H. F. KINGSBURY
R. W. McKINLEY

THE AMOUNT of available daylight is becoming quite important to people interested in the adequate lighting of enclosed spaces. The U. S. Weather Bureau now has operating a number of continuous daylight recorders recording horizontal illumination in various parts of the country. Like most previous investigators they are recording only horizontal illumination. This program is expected to expand as time goes on. Committee 27, Natural Daylight, of the International Commission on Illumination recommends that "studies be made of the percentage of working hours during which artificial lighting is needed, bearing in mind that it is not always possible to insure the provision of daylight sufficient both in quantity and quality for industrial and commercial work over the whole working day." The Daylighting Committee of the Illuminating Engineering Society decided at their meeting held in Washington, D. C. on August 29, 1951 to contact the Weather Bureau and offer any assistance possible in extending the work of the Weather Bureau in their daylight measurements.

AUTHORS: Product Development Physicist, Product Development Engineer and Development Engineer, respectively, Pittsburgh Corning Corporation, Port Allegany, Pa., and Pittsburgh, Pa.

With the above interests in mind, a continuous daylight recorder was designed and built and is now operating at Port Allegany, Pa., to provide more factual data indicating the number of hours of room occupancy during the year during which certain fenestration areas can be expected to receive on the average a given minimum of illumination. The illumination measurements being made are on the horizontal surface, and vertical surfaces oriented in each of the four cardinal directions. It is hoped that a correlation between the horizontal surface illumination and the vertical surface illumination available in any direction may be obtained which will indicate the vertical surface illumination in terms of the horizontal surface illumination at any given time of day or season of the year.

The continuous daylight recorder consists of an aluminum head placed at a high elevation in Port

Figure 1. The recorder head mounted 50 feet above the terrain.

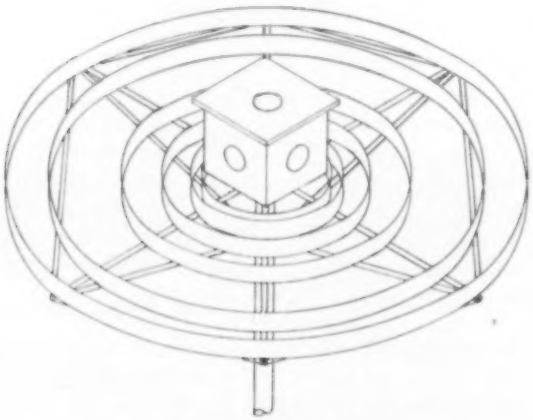

Figure 2. The artificial horizon.

Allegany. (Fig. 1) An artificial non-reflecting horizon (Fig. 2) is furnished so that variable ground conditions will not interfere with the results obtained. The effect of ground reflectance can be included in fenestration design by the application of factors related to specific job conditions.[1,2] This head is an aluminum box 6″ x 6″ x 6″. A Weston photronic cell (Model 856) is mounted on the top horizontal surface of the box and in each of the four vertical sides of the box. The cells are hermetically sealed, and are thus not subject to variations in calibration due to humidity changes, dust infiltration and the like. They are, however, subject to changes in calibration with extreme swings of temperature, and on the basis of available data on these cells, the temperature must be held within ±15F to obtain readings that are dependable to ±2 per cent. The temperature inside the aluminum head is thermostatically controlled and heat is supplied when the temperature becomes low, and cooling by the expansion of compressed air is supplied when the temperature becomes high, with the result that the temperature inside the box has been held within ±10F. The leads from the cells are connected to Weston (Model 741) 100 microampere meters equipped with special 200-ohm movements, so that the cells will have essentially

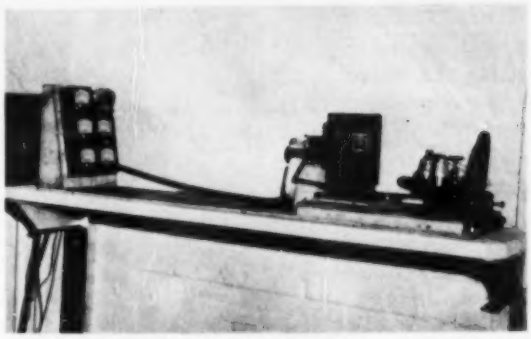

Figure 3. The continuous daylighting recorder meters, dater, camera, etc.

straight-line response over the range of light encountered. These meters are mounted on a panel along with an automatic dating device and a clock (Fig. 3). A picture of the meters, the date and time of exposure is taken on 35 mm film. The advantages of using this photographic method instead of a point by point recorder have previously been discussed.[3] Since the photographic method records the readings of all the meters simultaneously, there is no possibility of the light changing between the time the horizontal cell and the vertical surface cells are read.

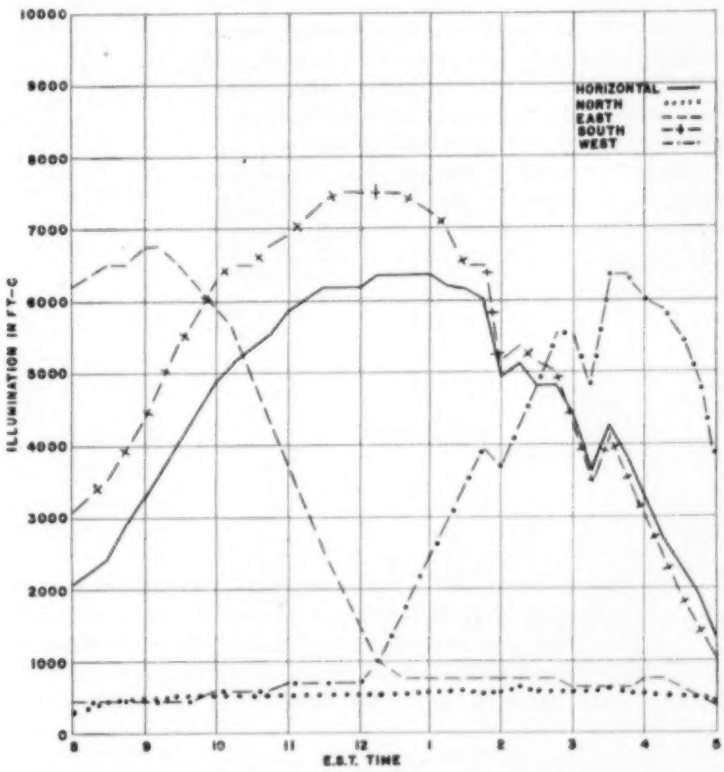

Figure 4. One's day's data collected by the continuous daylighting recorder.

The horizontal, east, south and west cells are "inconel" coated so that only one-tenth of the light striking the cell reaches its sensitive surface. This coating is necessary to eliminate the possibility of deterioration of the cells due to excessive irradiation and to keep the cells in the range which produces an almost straight line response. The north facing cell is not "inconel" coated since the illumination does not get much above 1500 footcandles. All cells are cosine corrected, and are corrected for visual sensitivity by means of a "viscor" filter.

The camera used to photograph the meter readings is a Graflex 35 mm photo-record camera, specially adapted to a Micro-Raptar lens. The camera is synchronized with a stroblite and is actuated by timers at appropriate intervals.

The data for this research are being collected from 8 a.m. to 5 p.m. EST daily. An accurate check is being kept to determine the number of overcast days and the number of sunny days during the year, the number of hours during the day in which the illumination is above 500 footcandles on the vertical surface and the number of hours during the day in which the illumination is above 1000 footcandles. For overcast days, the average vertical surface illumination is being determined.

One day's data are plotted on the curves in Fig. 4. When a sufficient amount of data are collected, a report will be made giving the results of the test. It is hoped that the data can be presented in such a manner that, by correlating with Weather Bureau data collected in various parts of this country, it will furnish illuminating engineers with information regarding the amount of daylight that may be expected on any vertical surface of interest.

The authors wish to express their appreciation to Dr. A. H. Baker and Mr. V. U. Bizzaro for the assistance they have rendered during the planning of the research and the building of the equipment.

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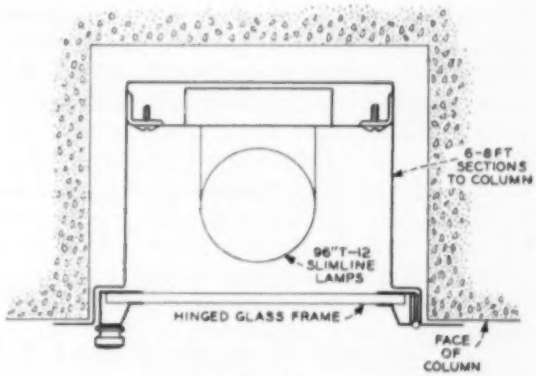
Lighting a Contemporary Church

Architect: Lawrence S. Whitten

LIGHTING, skilfully used, accents the attractive appearance of the new Central Park Baptist Church, Birmingham, Alabama, from its striking but dignified facade to its cleanly designed modern interior. In departing from traditional church lighting practice, the architect has planned this building with light as a prominent design element. Floodlighting the limestone facade provides a cheerful night-time welcome and makes visible enough of the design elements of the facade to carry into the night much of the feeling created by the daytime appearance of the church. In the sanctuary, a ceiling cove forms a pattern of interest and, at the same time, draws the eye toward the Baptistry, the focal point of the interior design.

Lighting the broad and towering facade was a problem, as its shallow depth and clean lines made the use of standard floodlighting equipment impractical. The architect solved this problem with a continuous row of fluorescent luminaires recessed into the back of each of the two columns.

A 4½-inch slot in the limestone facing of each column accommodates a continuous strip of six 8-



Continuous row of slimline lamps recessed in each column.

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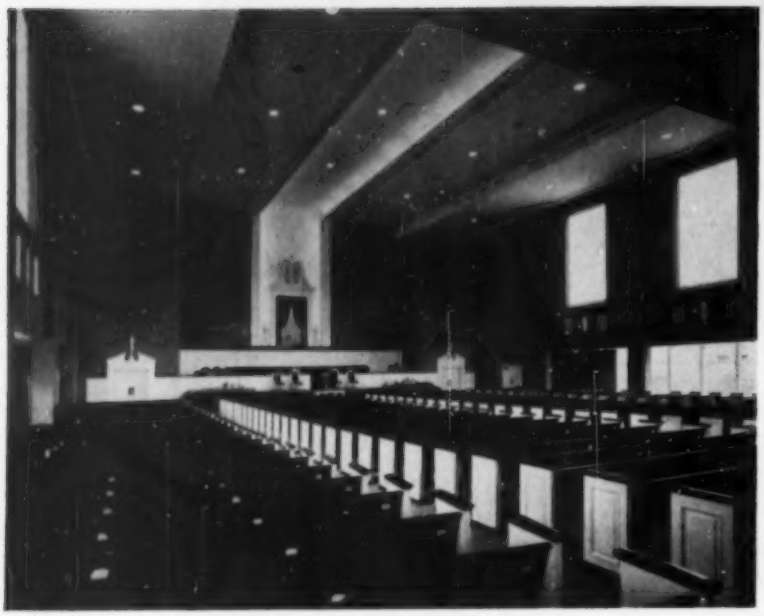
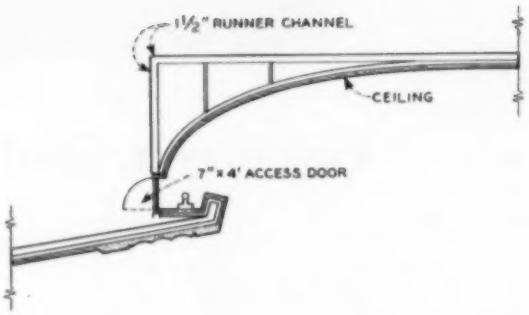


Access door (below) behind fluorescent strips for relamping and maintenance.

foot single-lamp slimline fixtures. These units are totally enclosed with hinged glass covers flush with the column surface. Ballasts are located in a 5-foot 8-inch pocket centered vertically in each of the concrete columns, directly behind the fixture slot in the 4-inch limestone facing.

Central feature of the auditorium lighting is the continuous cove, 7 feet in width, which runs from the Baptistry to the ceiling and continues along the full length of the ceiling to the rear of the auditorium. Downlights, recessed into the acoustical ceiling, supplement the general illumination provided by the cove. Special groupings of these recessed units are directed at the pulpit and the choir.

Dimmer controls and special circuiting insure a high degree of flexibility in the use of the auditorium lighting. When Baptismal Service is held, all fixtures but the cove are either dimmed or switched off. During regular services, the house lights are dimmed, while those on the pulpit remain at full intensity to highlight the pastor. The choir can be flooded with light as special musical



programs require. The fluorescent cove remains lighted at all times when the auditorium is in use.

One example of the thought given to maintenance in this installation is the access door provided just in back of each of the fluorescent strips in the continuous cove. Through these 7-inch x 4-foot doors, the fixtures can be relamped and maintained without the necessity of erecting temporary service ladders or scaffolds in the auditorium.

Progress Report in March IE

Publication of the annual report of the Progress Committee is scheduled for the March 1954 issue of ILLUMINATING ENGINEERING.

Dimming Hot Cathode Fluorescent Lamps

By J. H. CAMPBELL
H. E. SCHULTZ
W. H. ABBOTT

IT HAS long been the desire on the part of lighting engineers to find a method for controlling the brightness of fluorescent lamps over a wide range. It is the purpose of this article to describe a system of brightness control which increases the many advantages of fluorescent lighting while retaining circuit simplicity and ease of installation.

Filament Lamps

Methods for dimming filament lamps appeared soon after the lamp was introduced because a change in the applied voltage was the only fundamental requirement. Early methods included the water rheostat, iron wire rheostat and the step control using tapped resistors. Improvemnts in the smoothness and efficiency of the control were gradually made with the introduction of variable autotransformers and thyratron tubes. The amount of light emitted is directly related to the temperature of the filament so with voltage control the range of brightness can be considered infinite.

Fluorescent Lamps

Due to the complex characteristics of electric discharge lamps, and associated auxiliary equipment, a relatively narrow range of brightness change is practical with line voltage control. Since the fluorescent lamp has a negative resistance characteristic, it requires a ballast in series to control the current. For stable operation the voltage drop across the conventional reactor ballast should be about equal to the lamp operating voltage. When line voltage control is used to dim the fluorescent lamp the voltage drop across the ballast decreases and lamp voltage increases with reduction in current. For this reason only a limited decrease in lamp current can be accomplished before the circuit becomes unstable and the lamp arc extinguishes. This generally occurs at a point where lamp brightness is still 50 per cent of normal. Even with this limited range of two to one it is doubtful whether the lamp will start at the low brightness point because starting voltage is reduced in direct ratio.

In applications where it is desirable to have some control of lamp brightness it is possible to operate one lamp on two ballasts of different current rating. For example, a slimline lamp could be operated at 120, 200 and 320 milliamperes by switching between single lamp 120 and 200 milliamp ballasts or by operating the two ballasts in parallel. Since fluorescent lamps become more efficient at low current levels, brightness changes are not in proportion to lamp current so this system produces steps of 100 per cent, 75 per cent and 50 per cent lamp lumens.

One brightness control method[1] which has been used to some extent in England makes use of individual matching transformers with primaries connected in series with the line and a common variable resistor. This is an arrangement whereby a fixed number of lamps can be operated from one control unit. Any addition or reduction in the number of lamps per circuit requires a change in the value of the control resistor or the line voltage.

A dimming system for fluorescent lamps,[2] employing thyratron tubes is now being used in Europe. The circuit is designed for a special lamp which contains an inside conducting stripe to aid in starting and re-ignition. The control unit uses a rectifier to supply grid voltage to each tube and a separate peaking transformer for phase shift. This system is capable of providing a brightness range of 100 to 1 or better.

Cold cathode fluorescent lamps can be successfully dimmed by operating a number of lamps in series on a high voltage, high reactance transformer. Dimming is accomplished by varying the voltage to the primary of the transformer. This arrangement does not produce as wide a range of brightness as can be produced with hot cathode lamps, because of the relatively low maximum cold cathode lamp current. The high voltage required to start lamps in series makes it necessary to provide special lampholders to insure safety during maintenance. It also has the disadvantage of poor

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starting at very low levels of current since voltage available to start the lamps is inadequate.

Circuit and Lamp Requirements

When current supplied to hot cathode lamps is reduced, a point is reached where arc current is inadequate to keep the electrodes at a satisfactory electron emitting temperature. The emission for very low current is then supplemented by ion bombardment. This action strips the cathodes of active material and short lamp life results. In view of this, lamp electrodes must be heated continuously at a temperature which will produce sufficient electron emission at any point in the dimming range.

In order to provide smooth operation, the circuit should produce sufficient voltage to start the lamps quickly at minimum as well as maximum brightness. Sufficient voltage must also be available to re-ignite the arc each half cycle to avoid flickering.

Theory of Operation — Electronic Dimming Control

Control of the lamp brightness is accomplished by adjusting the interval of current conduction during each half cycle of the 60-cycle voltage. Two thyratrons are connected back to back so that the pair of tubes will conduct current for both polarities of the a-c voltage. These tubes act together as a synchronous switch which closes the circuit at a predetermined point in the a-c voltage each half cycle and opens at the end of each half cycle. In this way voltage is applied to the lamp for any desired fraction of the cycle. Fig. 1a shows the voltage wave applied to the entire lamp load when the interval of conduction is set for 90° or half of each cycle.

The abrupt rise in voltage at the leading edge of applied voltage is used to insure re-ignition of the fluorescent lamp on each cycle. The ballast for each lamp contains a choke which is in series with the lamp to limit the lamp current. Across the lamp is a small capacitor which suppresses radio interference and resonates the sharp voltage rise at the leading edge of the applied voltage to a higher peak value to start and re-ignite the lamp on each cycle. The oscillogram in Fig. 1b illustrates this voltage condition.

The point in the cycle at which the thyratron tube begins conducting is controlled by the grid voltage. A sine wave, variable in phase relationship to the line voltage is applied to the grid of the tube and the tube will fire or conduct when its plate is positive with respect to the cathode and its grid voltage is essentially zero. Referring to the circuit diagram of Fig. 2, each grid derives its voltage from two coils in series, one on T_1, which is constant in voltage and phase, and one on T_2 which is variable in voltage and phase. The sum of these two voltages results in a sine voltage of constant amplitude but variable in phase relationship. In this way the point in the cycle at which the grid is zero volts with respect to the cathode can be controlled.

Fig. 3 represents a vector diagram of the grid circuit. Vector AC represents the phase of applied line voltage and plate voltage. Vector AO represents the voltage of one of the secondaries of T_1 and is constant in magnitude and phase. Vector BC represents the drop across the total resistance in series with the primary of T_2. Vector AB is the voltage drop across the primary of T_2 and is variable in magnitude and phase. As the resistance varies, vector AB varies along the semi-circle ABC. Vector AF is the voltage induced in one of the secondaries of T_2. The turns ratio of the transformer T_2 is such that the maximum magnitude of AF is twice the magnitude of vector AO. The voltage applied to the grid of the tube relative to the cathode is the vector sum of AO and AF. The dashed lines show the addition resulting in the vector AD. The voltage AD is constant in magnitude but lags the plate voltage (vector AC) by an angle which varies from 0° to 180° along the semi-circle ODE.

The control elements of the circuit are resistors R_5 and R_6 one of which can be adjusted so the lamps will not be taken below the minimum brightness and the other selects the brightness at any point in the range. Rotating the control changes the resistance in series with the primary of T_2. Since both tubes are controlled by the secondaries of T_2 this single control regulates both tubes.

A small capacitor (C_1 and C_2) is connected between grid and cathode of each thyratron tube to suppress line surges. Without suppression these surges can cause the tubes to fire prematurely in the cycle giving a flash of light. The resistors R_1 and R_2 are used to limit the grid current to a small value while the grids are positive. R_3 tends to stabilize the lamp operation at very low levels by draining off any residual charge from the yellow line after each pulse of current.

The angle at which the tubes start conduction is a function of the ratio of the sum of R_4, R_5, R_6 and the primary resistance of T_2 divided by the inductive impedance of the primary of T_2.

Fig. 4a shows the entire cycle of current waveshape for five ratios of R/X_L (.850, 1.08, 1.32, 1.65

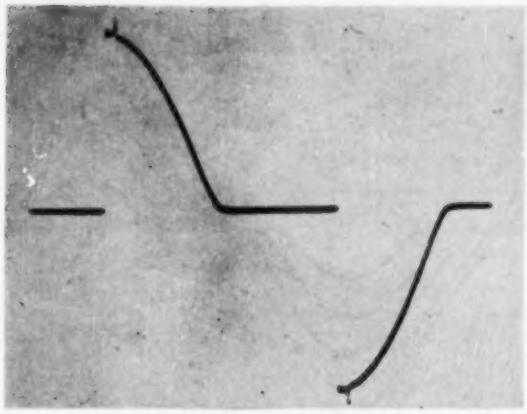

Figure 1a. Operating voltage applied to the lamp circuit for the 90° conduction point.

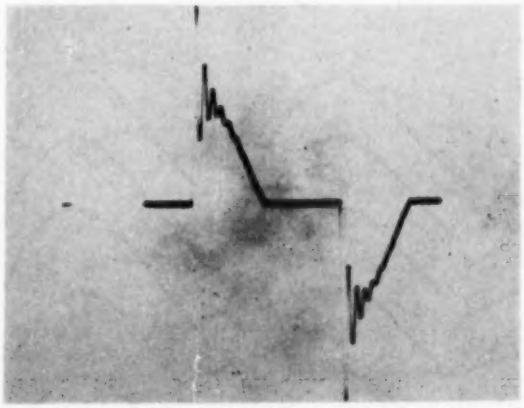

Figure 1b. Open circuit voltage applied to the lamp for the same point as Figure 1a. The high peak voltage is a result of the steep rise on the voltage of Figure 1a, applied to the L-C combination in the ballast. This peak insures starting and re-ignition on each cycle

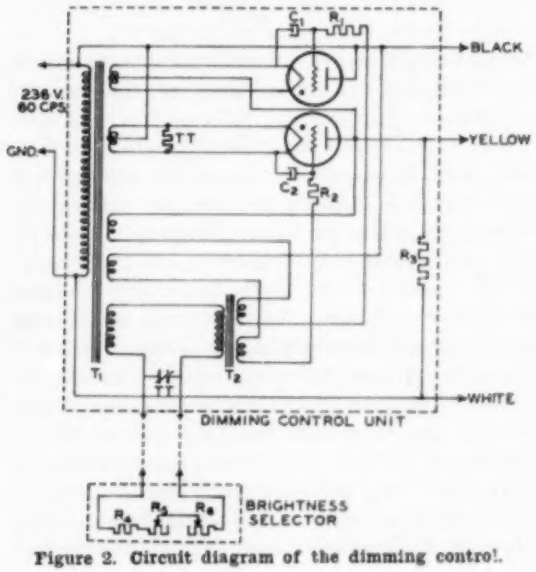

Figure 2. Circuit diagram of the dimming control.

and 1.93). These points correspond to the 20 per cent, 40 per cent, 60 per cent, 80 per cent and 100 per cent light output points. Fig. 4b shows the light output waveshapes for the corresponding ratios of Fig. 4a. The bottom line of this figure is the zero light reference level. Figs. 5a, 5b, and 5c show the relation of R.M.S. lamp current, average light output and conduction angle versus this ratio of R/X_L.

Lamp[3] flicker at full light output corresponds to single lamp operation with conventional ballasts. The percentage flicker as measured by photo-cell instruments increases as the lamps are dimmed. However, lamp flicker becomes less apparent to the eye as brightness decreases with the result being essentially the same at low brightness on the dimming circuit as conventional operation at full brightness.

The Distribution System

Referring to Fig. 6 only three wires are required to bring power from the control unit to the lamp load. A nominal 236-volt single phase line supplies power to the control. One common and one control line are needed to supply voltage for lamp arc current. The third wire by-passes the control to provide the cathode preheat transformers in the ballast with line voltage thus maintaining constant cathode temperature over the dimming range.

The Lamp Ballast

The lamp ballast consists of a series reactor for arc current control and two isolated cathode windings of sufficient voltage to keep electrodes at electron emitting temperature. The lamp load has a power factor of approximately 50 per cent lagging. Correction to over 90 per cent can be made by placing capacitors across the line on the input side

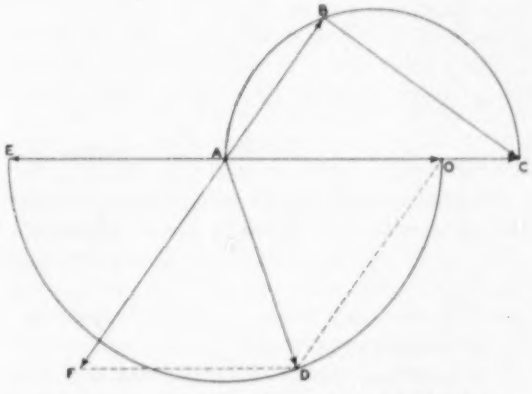

Figure 3. Vector diagram — grid circuit voltages.

of the control. Approximately 4 mfd. per lamp wi be required.

Characteristics of the Dimming System

In order to obtain the maximum range of light output, cathodes must be continuously heated. The instant start lamps such as the slimline group cannot be provided with cathode heat and, therefore, the system was designed for 40-watt preheat lamps only. Early ballasts were designed for either the starter type or Rapid Start lamps when the latter type was not available in colors. Due to the advantages of the Rapid Start lamp which is now listed in colors, it is anticipated that the ballast will be designed exclusively for the Rapid Start lamp.

Requirements for Starting

It will be noted in the description of Fig. 1b that a peak voltage is supplied to aid in starting the lamps. Since the effectiveness of the peak voltage in starting the fluorescent lamp depends on the capacity coupling from lamp to ground, there should be a grounded metal plate near the lamps; for most applications, fixture bodies or wiring channels will suffice. If open wiring on a wood panel is used there should be a one-inch metal strip running the entire length of the lamp and placed approximately ⅜ inch behind the lamp. The strip should then be connected to the grounded line wire through a ½-megohm resistor. Under normal conditions the lamps should start quickly and reliably at any point in the dimming range.

Brightness Range

The system provides for relative brightness varying at least 100 to 1. Under optimum conditions of line voltage and ambient temperature, and with well seasoned lamps, the brightness range can be increased to 250 to 1. New lamps may not start immediately at the low brightness level and it is recommended that these lamps be seasoned at normal brightness for a short time in order to provide the maximum dimming range for all lamps.

Color and Efficiency

Fluorescent lamps on dimming circuits offer several advantages over filament lamps: higher efficiency over the dimming range, lower operating costs, and better color control. Filament lamps become increasingly red as they are dimmed; fluorescent lamps change very little in color over their entire brightness range. A comparison of efficiencies of fluorescent and filament lamps appears in

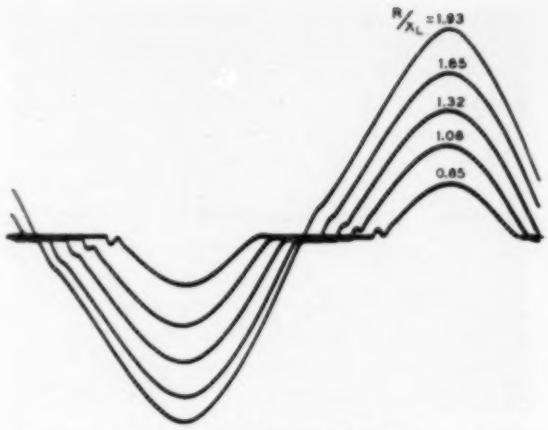

Figure 4a. Current waveshape corresponding to 20%, 40%, 60%, 80% and 100% brightness.

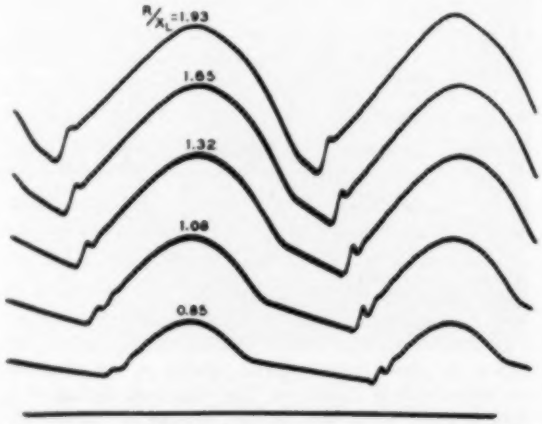

Figure 4b. Light output waveshapes corresponding to the points of Figure 5. The bottom line is the zero light reference line.

Table I; figures are for color of approximately equal chromaticity, with lamps at their normal brightness.

Fig. 7 shows a comparison of the approximate efficiencies of warm white fluorescent and 200-watt filament lamps for a wide range of dimming. No consideration is given to the change in color of the filament lamp as it is dimmed.

Fig. 7 does not include the losses of the ballasts or control equipment for fluorescent lamps. The total loss will vary depending on the number of lamps in the load. However, with 35 lamps on the control unit there will be a nearly constant loss of 4 watts per lamp over the dimming range. The individual ballast will have approximately 8 watts loss at the highest brightness and 2 watts at the lowest brightness. Losses of the control equipment for filament lamp dimming will vary consid-

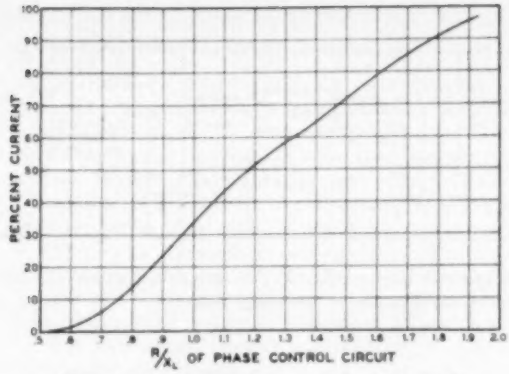

Figure 5a. **RMS current versus R/X_L ratio.**

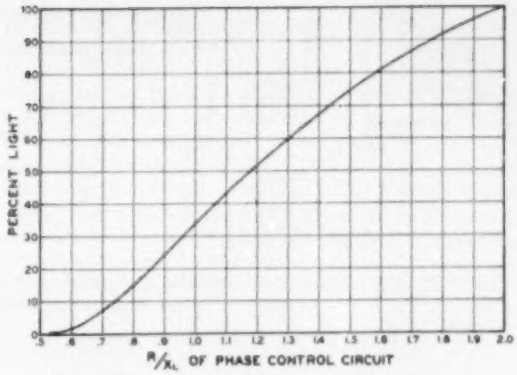

Figure 5b. **Light output versus R/X_L ratio.**

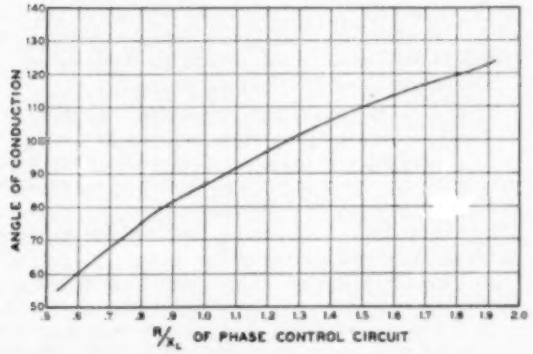

Figure 5c. Conduction angle versus R/X_L ratio. This angle divided by 180° gives the fraction of the half cycle that voltage is applied to the lamp load.

TABLE I.

Color	Lumens per Watt 40-Watt Fluorescent	Lumens per Watt 200-Watt Filament (Typical Filters)	Efficiency Ratio Fluor./Filament
White	64	18	3.5
Gold	33	15	2.2
Pink	26	8	3.3
Red	4	3	1.3
Medium Green	77	3	26.0
Medium Blue	27	1.5	18.0
Daylight	49	9	5.4

erably with the type of equipment and the total load.

Dimming Control and Ballast Design

The General Electric fluorescent lamp dimming control has three parts each of which may be located remote from the other two. The ballast and 40-watt lamp make up one part, the dimming control unit is the second part and the intensity control is the third part.

The ballast, which would be conventionally located in the lamp fixture, has two functions: to limit the lamp current in the usual way and to supply low potential power to heat the lamp cathodes continuously. Only three leads must be brought to the entire group of ballasts from the dimming control unit. The ballasts are connected in parallel, the maximum number depending on the rating of the dimming control unit.

Two models of the dimming control unit are available. One will control 35 (or less) 40-watt fluorescent lamps, and the other will control 8 (or less) 40-watt lamps. Both models operate from 236-volt 60-cycle supply lines. The heart of each unit is a pair of industrial thyratron tubes. The principal difference between the two models is the size of these tubes which determines the maximum number of lamps each unit will control. To protect the thyratron tubes in the control unit during initial operation, a time delay device "warms up" the tubes. (T. T. Fig. 2.) Both models are the same size in physical dimensions and may be racked side by side, or panel mounted side by side. Each model has a completely enclosed terminal box built in and provided with standard knock-outs for leads.

The intensity control is essentially a variable resistance. Its purpose is to set the time at which the thyratrons "fire" and pass current to the fluorescent lamps. The variable resistance is rather low in value (less than 1,000 ohms), hence the remote control lines are not likely to pick up stray signals to affect the brightness level of the fluorescent lamps. The intensity control operates at 25 volts or less, and is electrically isolated from the 236-volt supply lines. The intensity control may be used with either model of the dimming control unit. Several units may be controlled by one intensity control, but the variable resistor must be proportionately larger in wattage rating. More elaborate brightness controls using motor driven variable resistances may be devised to suit the needs of special applications.

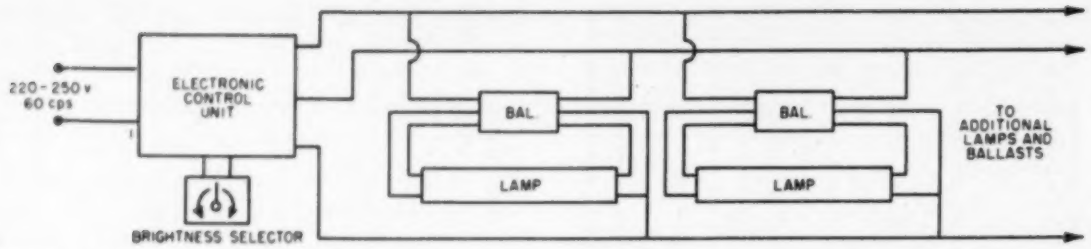

Figure 6. Block diagram of dimming system for fluorescent lamps. The control unit may be placed anywhere and two wires run to the Brightness Selector and only three wires to the lamp load.

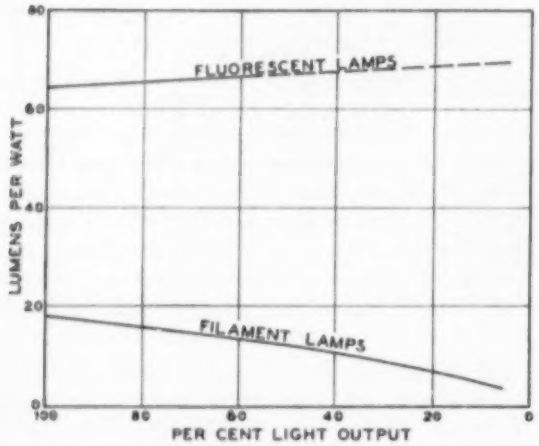

Figure 2. Comparison of lamp efficiency for the fluorescent and incandescent lamps over the dimming range for white light.

Applications

There are many applications for brightness control of fluorescent lamps. The greatest demand for this added flexibility of fluorescent lighting has come from the theatre and stage lighting field. However, many others can now make use of the advantages of fluorescent lamps with controlled light output. Television studios, auditoriums, restaurants, night clubs, hotels, display areas, show windows and experimental laboratories are included in the list of lighting fields for which this system is expected to serve a useful purpose.

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DISCUSSION

W. P. CARPENTER*: This paper was informative and new to me. Certainly the combination described fulfills a requirement for control of hot cathode fluorescent lamps.

I would like to ask the following questions:

1. Early in the paper there is mentioned "relatively low cold cathode lamp current." What is meant by this?

2. A time delay is incorporated, presumably for thyratron protection. What is its warm-up time from cold start? What is its recycling time when hot?

3. Are the ballasts the same as used for any other non-dimming fluorescent applications?

4. Does the thyratron dimmer have Underwriters' approval?

5. It was mentioned that the brightness ratio is approximately 100 to 1, and in some cases 250 to 1 with seasoned lamps. Please describe what this ratio means with reference to eye sensitivity with respect to blackout. Does a brightness ratio of 100:1 on the 40-watt fluorescent lamp take the lamp down to apparent blackout?

HERBERT S. GLICK**: In addition to applications mentioned by the authors, I think that there might be some applications in controlling lighting in darkrooms in the photographic manufacturing industry. I would like to add the following:

Lighting working areas for the manufacture of sensitized photographic material is a highly specialized task for several reasons:

1. The lighting level is extremely subdued.
2. Fixtures are specially designed to be light-tight and to hold filters and to meet other special requirements.
3. Lamp replacements must be made in extreme subdued light with a maximum of safety to film and personnel.

At Kodak Park, which is the largest photographic sensitized materials manufacturing plant of Eastman Kodak Company, our present practices and methods have been established over a period of many years and are based on the use of tungsten filament lamps. For darkroom lighting we are more interested in long lamp life than in high lumen output. Because fluorescent lamp life is now so much longer than filament lamp life we are now investigating the possibility of using fluorescent lamps in our darkrooms.

Although dimming is by no means one of our major requirements, we do have numerous applications where a

*Chief Engineer, The Superior Electric Co., Bristol, Conn.
**Engineering Department, Eastman Kodak Co., Rochester, N. Y.

simple and safe dimming control would open the way for us to replace tungsten filament with fluorescent lamps.

J. W. STRANGE*: The reference to the English use of a cascade dimming circuit in dimming fluorescent lamps gives a rather false impression of the early application in England. The first application was some years earlier in 1949 and the original intention was to meet stage requirements for a range of at least 400 to 1 in brightness and instantaneous striking at any point of this range. This was easily met by the combination of continuous cathode heating, adjacent earth and separate impedance control. Although the cost was about 25 per cent up on equivalent incandescent systems, it offered great advantages, in efficiency particularly, and found immediate application to cyclorama lighting and other theatre uses.

There are a number of variants of this early circuit, of which the cascade circuit is one, which found application where other limitations such as length of wiring are more important than range of dimming. Thyratron control is an example of one circuit which has commercial application only to relatively large installations where the range of dimming is not so critical. The cost of the control gear makes it prohibitive for smaller numbers than about 8 or 10 lamps.

There are a number of points in the paper which are not quite clear. No indication is given of the size and rating of the control resistance but one estimate would indicate that it would have to carry a fairly heavy current. It also appears that the circuit is limited to supplies in the region of 236v. The authors, in preparing Table I have fallen into the common error of not including ballast losses of the fluorescent lamps, and have also taken initial and not average values. This gives an over-optimistic picture.

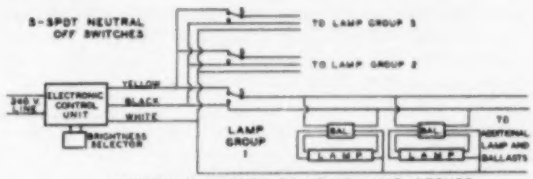
When dimming circuits are used for such purposes there is a marked relative improvement of the fluorescent lamp compared with the incandescent lamp when this is "on check." This may be as much as 2/300 per cent. This does not necessarily apply to the present circuits which are more suitable for auditorium lighting where the lamps are either full up or out.

One of the major disadvantages of thyratron circuits is that leading circuit ballasts cannot be used and even with separate power factor correction a factor of only 90 per cent can be achieved. In our experience, mercury vapour valves are unsatisfactory due to the long warm-up period, and their sensitivity to temperature; for this reason we prefer the gas-filled type.

J. H. CAMPBELL, H. E. SCHULTZ and W. H. ABBOTT**: The authors wish to thank Mr. Carpenter for his comments and the questions he raised regarding the fluorescent dimming system. It is hoped the following comments may provide the answers.

1. The relatively low current referred to in connection with cold cathode lamps applies to a lamp design limitation. Because of the nature of the electrodes in cold cathode lamps the lamp current is limited to a maximum of about 200 milliamps, the most common rating being 120 milliamps. Hot cathode lamps of the 40-watt rapid-start design used in the dimming circuit have a maximum rating of 425 milliamps.

2. The time delay relay period is 20 seconds for the 8-lamp dimmer model and 60 seconds for the 35-lamp dimmer model. After the main power switch has been opened, 20 minutes must elapse before reclosure, to allow cooling to recover the above time delays. However, it is not necessary or desirable to turn the dimmer off when complete blackout is needed. This can be accomplished by means of a switch in the control line, thus allowing the thyratron tubes in the dimmer to remain heated so the brightness selector can be operated without delay. If it is desired to turn the lamps on at full brightness without waiting for the dimmer control relay, the thyratron output can be short circuited by means of a simple switch. The illustration shows how both conditions can be satisfied by means of a single pole double throw switch with a neutral position.



SWITCHING METHOD OF USING LAMP GROUPS AT FULL BRIGHTNESS, ON THE DIMMING UNIT, OR OFF

Groups of lamps operating on the same dimming control may be switched independently to any one of the three positions without affecting the control or other groups of lamps.

3. No. A ballast for the 40-watt rapid-start lamp, designed to match the characteristics of the dimming control is needed.

4. The dimmers have been submitted for Underwriters Laboratory consideration. Only preliminary examination has been made at this date.

5. We could not say that 1 per cent of maximum brightness represents blackout. However, in cases where complete blackout is needed, the brightness selector when turned to the minimum position can be arranged to operate a switch to turn the lamp load off. Most dimming cycles are short enough in time so the eye cannot become dark adapted sufficiently to detect a marked change from 1 per cent brightness to zero.

The authors wish to thank Mr. Glick for presenting his idea on the use of the dimming circuit for the photographic manufacturing industry. This appears to be another application where fluorescent lamps are preferred to filament lamps when methods are available to control brightness of both sources.

This transfer of information helps the application engineer to understand the problems involved in special lighting installations and to adapt new equipment to meet the requirements.

The authors wish to thank Dr. Strange for his discussion, and hasten to assure him that our reference to one method of dimming employed in England was intended to give credit for development work accomplished there on a somewhat different approach to the problem. Space allotted to this paper did not allow for a complete review of the many circuit combinations developed here and abroad for dimming fluorescent lamps.

The current carried by the control resistance is comparatively light, since it is only 125 milliamperes at maximum and 31 milliamperes at minimum. The brightness control is a 500-ohm potentiometer rated at only 5 watts. The small size of this unit together with the low voltage applied to the grid phasing circuit of the thyratron tubes (24 volts), makes it convenient for location anywhere in the lighted area.

Dimmers were designed for 236-volt operation in order to

*Thorn Electric Industries Ltd., London, England.
**Authors.

operate the maximum number of lamps on a pair of thyratron tubes. Where 236-volt circuits are not available, a single autotransformer can be used to step-up the voltage from either 208 or 120 volts.

With regard to the omission of ballast losses Table I, it is the custom here to show efficiencies of fluorescent lamps and losses of ballasts separately because overall efficiency will vary depending on the make and type of ballast employed. Approximate ballast losses are discussed in a subsequent paragraph. Initial lumens for both filament and fluorescent lamps are the same as the published values. In the case of fluorescent lamps, published lumens are 100-hour figures. An average figure would be difficult to assign since depreciation with life will vary considerably depending on the number of starts the lamp receives. A filament lamp also depreciates during life on a curve similar to that of a fluorescent lamp. The ratios of Table I are conservative for lamps operating below normal brightness due to the decrease in efficiency of the filament lamp while fluorescent lamps increase in efficiency as brightness is reduced. (See Fig. 7.)

The primary circuit power factor can be corrected to 90 per cent lagging at full output. Power factor at minimum output will be leading.

Thyratron tubes of the type used in this device are gas filled for the 35-lamp dimmer and mercury vapor for the 8-lamp dimmer. In each case the warm-up time is approximately one minute.

Street Lighting Photocell Control Calibration Cabinet

Discussion of paper by W. N. Lindblad and L. C. Edwards

(Published October 1953 issue of ILLUMINATING ENGINEERING, p. 509)

R. J. PALMER*: This paper is very timely, at least so far as the Detroit Edison is concerned. We have recently given some thought to improving our own method of photoelectric control calibration and so any ideas such as those contained in this account are welcomed for consideration.

There are approximately 600 photoelectric control units on the company lines in street lighting service. This does not include the photoelectric controls which are integral with luminaires and control approximately 400 individual lamps.

At present there are but two test sets in operation on the system. Our Meter Department has one, and that group is charged with the responsibility for acceptance testing of all controls as received from vendors. The other test set is in the company Radio Laboratory and that group has the responsibility for routine testing and maintenance of electronic type controls. Footcandle measurements are made to determine the illumination level of both turn off and turn on. This is to check against trouble reports that come in from the field. Quite often photocell controls are blamed when other equipment is at fault.

Both of the test sets are equipped with constant-voltage transformers and footcandle meters having "Viscor" filters. Beyond this, different principles of operations are employed.

That which is in the Meter Department has a 50-watt projection type lamp enclosed in a lamp house. The light is directed through an aperture to a relatively large diffuser and from there to the photo control location. The projection lamp is used because its higher lumens per watt provide a better color temperature than does the standard incandescent lamp. The light intensity is controlled by varying the aperture with an iris diaphragm. This results in no change of color temperature. The other test set uses a standard 100-watt incandescent lamp, and the intensity is controlled by varying the lamp voltage. This does vary the color temperature.

The experience gained from these two units has shown that it is not especially desirable to vary color temperatures during the test of photo sensitive devices particularly when making acceptance tests. Also, the procedure does not lend itself to satisfactory testing of mixed groups of photo sensitive controls incorporating both blue and red sensitive tubes. We have found that to obtain uniformity of control action it is necessary to establish what might be termed "equivalent" footcandle intensities of incandescent light energy. These are the incandescent light intensities which will have the same energizing influence on the photo tube as does an arbitrarily established daylight intensity. The variations because of color temperature differences between daylight and artificial light are as much as 25 per cent as read on the footcandle meter, if only the blue sensitive tube is considered. If the red sensitive tube is added, the variation becomes as much as 75 per cent.

It is with the foregoing in mind that we question the use of resistors in series with the calibrating lamp as a means of varying light intensities. Also, when it comes to acceptance testing, we believe that the values of 1.3, 1.5, 1.7 footcandles are too limited.

The instructions for use of the calibrating box raise three other questions.

1. Is anything of value gained by having a thirty-minute preheat period for the control devices over, say a three- to five-minute warm up period? The half hour time implies the need for a moderately elaborate pre-heat rack to accommodate the various designs of control units, or else much testing time is lost because of preheating in the calibration cabinet.

2. The use of an auxiliary bright lamp to provide 150 footcandles, and then suddenly by switching, dropping the intensity to 1.5 plus or minus .2 footcandle does not simulate the rate of decrease in daylight intensities. Because of the delay and feed back characteristics of controls, it seems that more reliable results might be had if the auxiliary

*Detroit Edison Co., Detroit, Mich.

bright lamp is reduced in intensity to a zero value at a rate that roughly corresponds to the delay characteristic of the control being tested. This decrease in intensity, while not as slow as that of daylight would permit the control action to follow the change in a nearly normal manner. A gradual change of light is more useful in calibration than rapid changes because relay operations can better be observed.

3. The use of a black cloth hood over the control being calibrated indicates that the control is susceptible to extraneous light which may strike a glass cover from other than a frontal direction. Would it not then be better to place the control unit within the calibration box so as to be effectively surrounded with light just as would be the case in most field installations? Incidentally, it has been found with the Detroit Edison Co. experience, that insofar as frontal light is concerned, it makes little difference if the glass cover is in place or removed. This, of course, does not apply if the unit in question employs a concentrating lens.

As a concluding comment, the idea of containing the test set in a box is quite attractive. By way of contrast the present Detroit Edison Co. routine test in the Radio Laboratory is contained in a small darkened room. It can be readily seen that the box has advantages in terms of more efficient utilization of light sources, no need for special dark room ventilating equipment, and much less confinement for the operator. There are, however, some advantages in having a dark room. Relay operations cannot be observed or heard in a calibrating cabinet. In many cases, relay trouble caused by arcing has been detected in our dark room that would have been missed in a relay cabinet.

ROY E. DAHLIN*: We were very happy to learn of this photocell control calibration cabinet that has been developed by the authors. In the Southern California Edison Company, we have developed a test unit for photoelectric street light controllers and from our experience, the following comments are offered relative to the paper.

The unit described in this paper appears to have the advantage of extreme simplicity, yet appears capable of producing a degree of accuracy (for certain types of controllers) that would be considered acceptable for production testing.

Where all the different types of units to be tested use photocells having similar spectral responses, then the use of a test light source of most any reasonable color temperature will produce tolerable results once coordination has been established between test unit results and field light intensity determinations. The testing in such a unit of an assortment of types, some containing a vacuum type photocell (RCA-IP39) and others, the gas-filled type (RCA-IP40), would I think result in a wide discrepancy between "on" (or "off") times for the two types under field conditions where the sky color temperature is quite different from that within the test unit.

The gas-filled IP40 is particularly sensitive to color temperature. Investigations along this line revealed a change in turn-on time for a given unit containing the IP40 photocell of 14 minutes between approximately 3500K and 5000K. These points represented maxima and minima on the curve plotted for color temperatures ranging from 2000K to 12,000K. The unit was initially adjusted to turn on at 1.5 footcandles at 7500K. The maximum deviation in turn-on time from this point was 11 minutes. Tests on other units employing the IP39 tube showed only approximately half the change in turn-on time for various values of color temperature within the range tested.

It is also noted that the method described is of the static type, i.e., no allowance is made for the changing light intensity under normal field conditions. This effect is negligible for units having little built-in time delay but for units such as the Fisher-Pierce model 61300 it is a sizable factor.

We have considered it worthwhile to determine the "on-off" differential for each unit tested in order to obtain assurance that cycling in service will not occur. We had experienced some difficulty with some of the first units we purchased in this respect; however, you will note that we specify an "off" value not exceeding 1.0 footcandle of the "on" value as compared to P. G. & E.'s 2.0 footcandle differential. It would therefore be expected that their differential is large enough to preclude any possibility of cycling.

It is gratifying to note that the P. G. & E. investigations on the rate of change of daylight at dusk at the 1.5-footcandle level check with our results to within about 20 per cent. At dawn they show four minutes between 1.5 footcandle and 3.5-footcandle levels compared with 3.5 minutes from our investigations.

We would be pleased to receive any information that might be available on north-sky color temperatures in the region of 0.5 to 2.5 footcandles as determined by others in this field.

J. W. STEINER*: This paper is an excellent example of a practical approach to a maintenance problem by a user. It is entirely possible that a modification of this technique may be practical in quality control by the manufacturer.

Two points probably deserve additional comment, I believe. First, some commercial controls use red sensitive photocells and others use blue sensitive. In either case it should be understood by the reader that a 1.5-footcandle response to the S-14 10-watt daylight blue lamp color may result in a considerably different response level for natural daylight. Our experience has shown that a blue sensitive cell will respond at 2 footcandles daylight compared with 3.8 footcandles for tungsten illumination through the daylight blue bulb. The service record reported in the paper indicates that the 1.5-footcandle tungsten blue level selected results in the desired response to natural daylight for this particular utility and area. It would be interesting to know whether blue or red sensitive cells were used in this study.

A second, but minor point, is that the color produced by the calibrating lamp will vary with the resistance control used to vary test level, though this is not necessarily significant for the application being reported.

W. N. LINDBLAD**: Early in the survey we anticipated great differences because of the fact that some controls had red sensitive and some blue sensitive cells. Some attempt was made to determine the color of the north sky at sunset in order to select which type had better be used. The color variation was so great, however, as to defy intelligent classification or averaging.

Both red and blue cells were used in our survey to determine total annual on-hours. The difference in total on time of the two types was too small to be significant.

Recently the manufacturer who used red sensitive cells in his controls, has announced a change to the blue type so that now, to the best of our knowledge, all six manufacturers making this type of control will utilize blue sensitive cells.

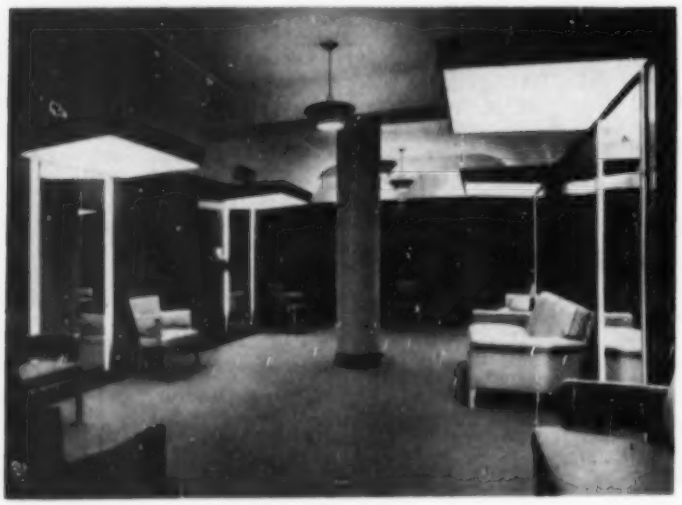
*Southern California Edison Co., Los Angeles, Calif.

*Westinghouse Electric Corp., Lighting Division, Cleveland, Ohio.
**Co-author, Pacific Gas & Electric Co., San Francisco, Calif.

Lighting to Make the Most Of a Mirror

Mirror lighting for an island unit is here provided by a custom-built four-lamp fixture using 48-inch slimline lamps. This installation, at Paul Steketee & Sons, Grand Rapids, Mich., provides 100 footcandles at 30 inches above the floor. Lighting engineer: H. P. Earley, Consumers Power Co., Grand Rapids.

Another custom-built unit, in the men's fitting room area at Harry Suffrin, Detroit, supplies 125 footcandles at each of the mirrors for customer's inspection and to aid tailors. Each mirror has a 3 x 4-foot canopy with one-inch plastic louvers. Each canopy contains six 30-watt standard cool white lamps; and on each side of the mirrors are 72-inch T8 lamps. Lighting engineer: H. J. Miller, Detroit Edison Co.

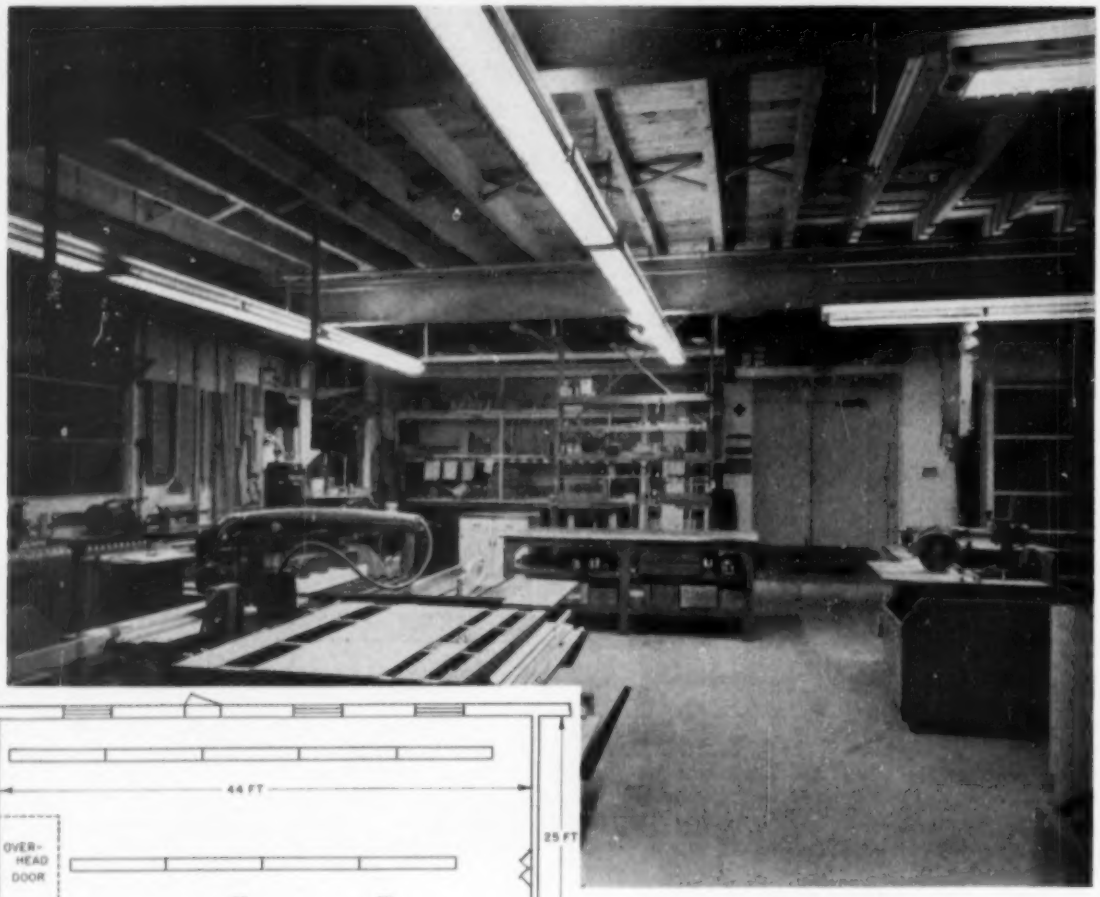


Photos and data courtesy of *Picture Your Lighting*, Madison, Wisconsin

Behind the lower part of each illuminated side panel a 48-inch 40-watt T12 strip with warm white lamps is used for good color rendition of gowns; mounted above it, a 20-watt soft white lamp provides a flattering light on the face of the customer. The ground glass diffusing panels are mounted in wooden frames built by the store carpenter. Installation is at Colonial Shop, Cincinnati. Lighting engineer: Harold J. Gruber, Cincinnati Gas and Electric Co.

Reduction of apparent ceiling height, a salon atmosphere, and a modeling light to accent furs were the objectives of mirror lighting in Carl A. Laabs, Inc., Milwaukee. The hung ceiling diffuses light from the overhead 150-watt R40 spotlights, and two additional spots at the sides of the mirror give a modeling effect, with a total of 50 footcandles on the vertical in a normal viewing position. Lighting engineer: E. H. Shaefer, Wisconsin Electric Power Co.

Eight 48-inch one-lamp channels with reflectors and four recessed adjustable spots produce 75 footcandles on the customer at Dorothy Bullitts Inc., exclusive dress salon in Ardmore, Pa. Deluxe warm white lamps are concealed in the valance around the mirror and vertically behind plastic strips where mirror sections join. The spotlights follow the contour of the mirror, on 2-foot centers. Lighting engineer: W. C. Hoch, Jr., Philadelphia Electric Co. This installation won second prize in the 1953 contest for "My Most Interesting Lighting Job," conducted by the Philadelphia Section of I.E.S.



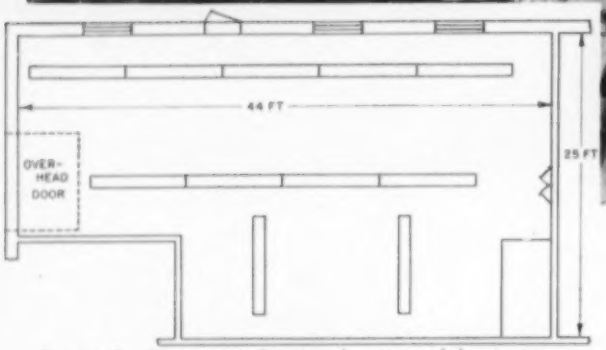


Figure 2. Plan view showing location of luminaires.

INSTALLATION AT
BUCHERT MANUFACTURING COMPANY
EASTON ROAD, HORSHAM, PENNA.

Lighting a Woodworking Shop

LIGHTING OBJECTIVE: To illuminate a cabinet-making shop with a minimum of glare on shiny machine surfaces without local lighting.

GENERAL INFORMATION: This shop makes cabinets for custom-built kitchens. Figure 2 shows the dimensions of the area. Ceiling height is 11 feet. Reflectances are as follows: ceiling 56%, walls 50%, floor 26%, furniture 30%. The machine arrangement is subject to change.

INSTALLATION: Quaker City #SL2-96 NCOM louvered luminaires containing two 96-inch T12 slimline fluorescent lamps operated at 430 ma are mounted on 9-foot centers 9 feet above the floor. After 200 burning hours the illumination on the working plane averaged 40 footcandles, with brightnesses as indicated below:

luminaires at 30°	860 ft-L
ceiling	20 ft-L
walls	23 ft-L
floor	26 ft-L
furniture	30 ft-L

Lighting designed by William C. Hoch, Jr., of the Philadelphia Electric Company.
Lighting data submitted by William C. Hoch, Jr., Philadelphia Electric Company, as an illustration of good lighting practice and to aid in the design of similar installations.

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The Orientation Reflex

By H. L. LOGAN

This paper discusses the effects of lighting systems on involuntary human action. It shows that objective orientation is largely a function of the visual stimulus, and that safe reactions to environmental hazards are therefore dependent on specific lighting distributions. The orientation reflex is described in some detail and its remote effects in the body illustrated by an experiment on muscular tension. The use of the flux diagram in avoiding lighting distributions that generate inadequate visual clues is described, and typical situations involving misleading visual clues are illustrated. Data are also given with respect to safety lighting levels, and a revision of our thinking on this phase of the subject is indicated.

AS LONG as there have been living things that moved there has been a means of perceiving light. Stationary forms of life have no eyes. Plants have no eyes and do not need them.

Visual organs became necessary to the survival of life when living forms developed locomotion. When living forms move they are exposed to a wide range of conditions, so some positive means of recognizing the benefits and dangers in the environment is necessary. An organ that will respond to light is the principal means. "Almost the very first animals that were capable of locomotion found that by means of responsivity to light and shade, they could most readily locate food — either food that stayed still or food that moved a little less rapidly than themselves."[1]

Primitive light responsive organs (Fig. 1) accept light unselectively from any direction, and the animal possessing them has only the vaguest sort of "vision" consisting of a general, patternless sensation of light. It cannot "see" as human beings understand the term, but the impulses set up by light in the network of nervous connections leading from the light-responsive organs to the muscles — the motor system — of the animal, causing survival-type reflex motions.

This arrangement, a means of receiving visual radiation, a means of converting it into nerve impulses, and a tie-in of these nerves with the animal's motor system, is the principal means found in moving-living-creatures for ensuring safe or beneficial responses to their environment.

This is the orientation reflex in its simplest terms; and light-responsive organs began, so-to-speak, as automatic safety devices to ensure survival. That is still the *primary* function of eyes.

Subjective and Objective Orientation

Orientation is regarded in two aspects: subjective and objective.[2] Subjective orientation is awareness of position in space, that is, whether upright, upside down, inclined, lying down, stationary or moving. Objective orientation is awareness of position and rate of movement with respect to *other* objects.

Subjective orientation is largely operated by the vestibular and kinesthetic elements of the orientation triad (Fig. 2). Objective orientation is largely a function of vision. Vision cannot operate without light; and safe, successful objective orientation in a physiologically normal person *is principally a matter of proper lighting.*

This is another way of saying that the cause of failures in normal people to avoid hazards that operate more slowly than the orientation reflex, *may lie in faulty lighting.* When it does the accident arises from visual clues that are inadequate to trigger the involuntary orientation reflex; or from misleading visual clues that trigger a defective involuntary response.

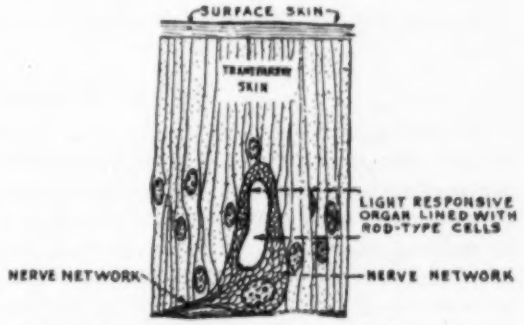


Figure 1. Section through transparent skin of earthworm, illustrating light-responsive mechanism.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 14-17, 1953, New York, N. Y. AUTHOR: Vice-President in Charge of Research, Holophane Company, Inc., New York, N. Y.

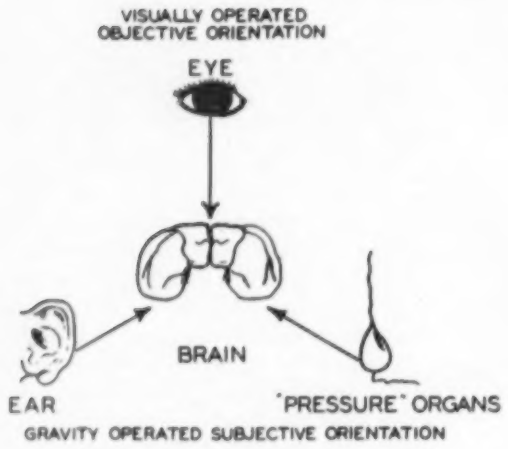


Figure 2. The orientation triad.

We can consider two general classes of accidents for the purpose of this discussion, those that occur outside the sense range, and those that occur within it. Examples of the first class include events that happen more swiftly than the rates of perception and protective reactions of the individual — such as explosions or events of which the senses cannot warn us, such as the presence of electrical charges, dangerous, odorless gases or harmful radiation.

Accidents from causes which the senses are not adequate to protect us against must be mechanically monitored by devices which will give us a sense warning of the impending event in sufficient time, and by training workers to observe necessary precautions.

We are primarily concerned here with accidents of the second class, that is, events that are detectable by the senses and operate more slowly than the rates of perception and involuntary response of the individuals concerned. Falls, falling objects colliding with stationary objects and contact with moving machinery are some examples of accident causes in this classification. The orientation triad of the individual is involved in this class of accident.

Objective Orientation

The fundamental nature of the objective aspect of the orientation reflex can be gauged from the fact that reflex orientation of the optical axes persists "in monkeys which have been decerebrated at the exact cephalic boundary of the anterior corpora quadrigemina."[3] That is, its roots lie deeper in the nervous organization than the higher (cortical) nerve centers of the brain; and at least as deep as the so-called optical thalamus[4] (the "ancient" brain) which is believed to be the seat of our feelings.

The objective orientation reflex by-passes the will, or rather it never reaches the higher cortical centers through which the will comes into play. The will is slow to act. It must receive data, compare the data with past experience, evaluate it, arrive at a judgment and then give the necessary commands to the nervous system to act. This makes for delay in emergency situations when speed is the essence. "It is known that the thalamus (roughly) appears (directly) connected with affective . . . life, and the cortex, farther removed and isolated from the external world, has the effect of inducing 'this delay in action'."[5]

If man had to take the time to think to act in the face of emergency survival threats his environment would destroy him. It is the automatic mechanism of the orientation reflex that permits man to engage his attention on the line of sight, without constant, conscious regard for the potential hazards of his environment.

The Human Eye

Inspection of Fig. 3 may make this clearer. There are, as is well-known, two types of light receptors in human eyes, rods and cones. The tiny spot in the central region of the retina, called the fovea, is completely packed with cones. We *see* with the fovea. Man has a *line of sight* which must connect the object of regard with the fovea through the lens. He only sees *clearly* along his line of sight.

Away from the fovea the rods begin to appear and quickly become more numerous. Throughout the entire eye they outnumber the cones twenty to one. Their tie-in with the motor system of the body is therefore dominant in the operation of the objective orientation reflex.

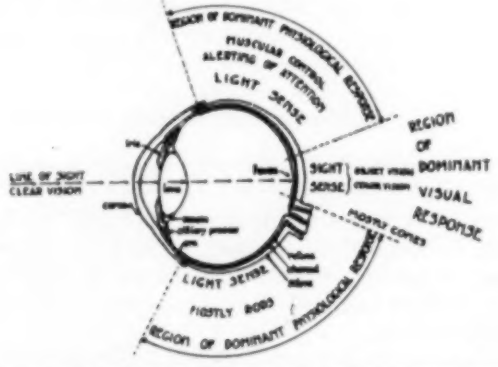


Figure 3. Section through human eye illustrating areas of dominant visual responses and dominant physiological response.

Figure 4. Some facial muscles active in vision. a. Frontalis. b. Corragator. c-d. Orbital and palpebral orbicularis. e. Levator labii sup. nasi. f. Zygomaticus minor. g. Orbicularis oris. h. Zygomaticus major. i. Depressor anguli oris.

The Motor System

Despite the efforts of investigators such as Dr. D. B. Harmon, there is among lighting engineers little awareness of the extensive degree to which the operation, regulation and control of the motor system of the body is subservient to the visual sense. This subserviency, working at the involuntary level, is continuous in the conscious state. It also has important repercussions in the unconscious state that are beyond the province of this paper.

An appreciation of its extensive nature requires some anatomical remarks. Quoting from H. C. Weston's recent paper on "Visual Fatigue,"[6] "In binocular vision no less than twelve muscles, six per eye, are involved in every movement and act of fixation of the eye. Four other muscles, two inside each eye, control the aperture of the eyes; these are the pupil constrictor and dilator muscles. Another two muscles adjust the curvature of the lenses . . . and another four muscles, two pairs, act to open and blink the lids of each eye." All twenty-two of these muscles act reflexly (involuntarily) but sixteen of them are also subject to voluntary control. "They work not as independent units but in groups with delicately co-ordinated actions." Also, "some of the facial muscles, shown in Fig. 4, as well as those of the neck are involved as accessories" in visual activity.

Then visual activity may, and frequently does, involve the entire motor system of the body, either reflexly or voluntarily, and either by way of inhibition (tensing or freezing) of all movements "which might mean a failure of the eyes to gather all the sensory impressions needed," or by way of partial or complete re-orientation of the body in response to a progressive or sudden change in the visual stimulus, or by "readying" of the system to meet a potential change.

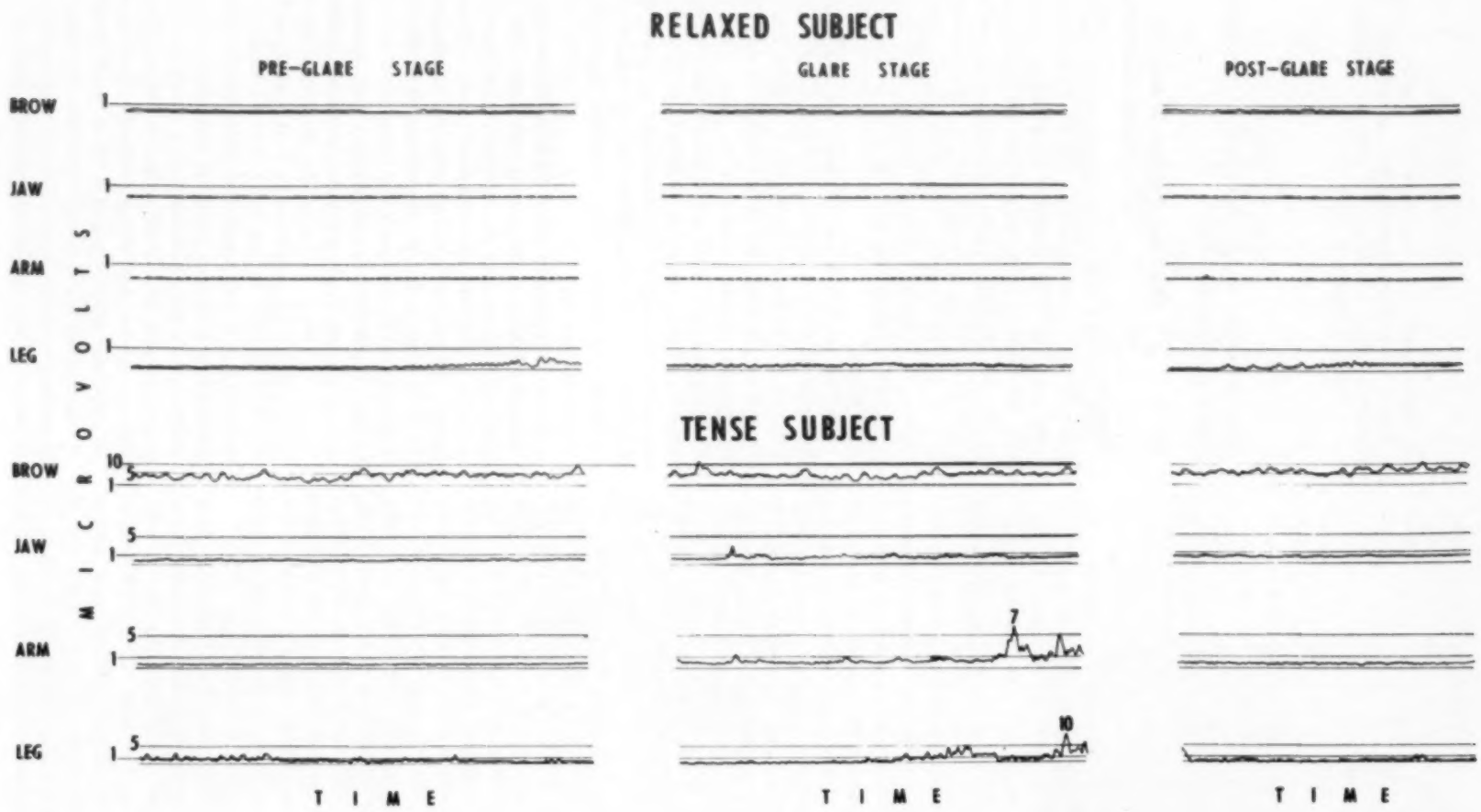
Muscular Tension as Related to the Orientation Reflex

This is shown well by the graphs of the electric potentials in muscles given in Fig. 5. Two subjects were tested by R. E. Lange of the Chicago Laboratory for Clinical Physiology, under the supervision of Dr. E. Jacobson.[7] One subject was devoid of chronic muscular tension and so was clinically normal in this respect. The other subject had a degree of chronic muscular tension, and represented an unknown but possibly large group in the population.

Electric potentials in the brow, jaw, arm and leg muscles were continuously recorded for both subjects, for twenty minutes prior to the introduction of peripheral glare in the field of view; then for twenty minutes' exposure to glare; then for twenty minutes following the removal of the glare stimulus. Space does not permit reproduction of the entire recording as the finished tape was 200 feet long. The sections shown in Fig. 5 have been carefully selected as truly representative of each twenty-minute run.

It can be seen that the record for the normally relaxed subject is practically the same for the three periods; that is, the introduction of glare did not raise the muscular tension level. Relaxed people are little affected by glare, as surmised by H. C. Weston in his paper previously referred to, although he did not prove the point.

The record for the chronically tense person is quite different. To begin with, the potential difference in the brow, jaw and arm muscles of the relaxed subject remained steady at threshold, and in the leg muscles varied from that to about 0.75 microvolt as a maximum. The brow muscles of the tense subject show a potential difference varying from eight to twenty times that of the relaxed subject; but, and this is a significant observation, it did not appreciably change with the introduction of glare, nor with its removal. That is, contrary to a widely held belief, muscles directly accessory to the visual sense may not offer the best location to check for glare effects, although the percentage of



Muscular Tension Recordings: Jacobson Method.

Figure 5. All recordings for the four locations for each subject were made simultaneously on the same tape, and so at different scales. Their full significance will not be evident unless scale differences are closely observed.

instances in which this holds true is not known. Changes due to glare in the vicinity of the eye region doubtless have the function of eye protection; while tensions in the larger muscles of the organism, including the limbs, presumably have the function of removing the organism from the stimulus.

The jaw muscles of the tense subject show a steady potential difference of 0.5 microvolt in the pre-glare stage, which rises to a peak of 2 microvolts in the glare period, dropping to a steady 0.7 microvolt in the post-glare stage. While a definite change, it is small. The large change comes in muscles remote from those accessory to voluntary visual activity — the arm and leg muscles, illustrating the extensive degree to which the visual sense operates the body.

The potential difference in the arm muscles of the tense subject in the pre-glare stage is about 0.5 microvolt, but rises in the glare stage to a peak of about 7 microvolts, from which it drops back to a steady 0.5 microvolt in the post-glare state. The leg muscle potential difference varies from threshold to 2 microvolts in the pre-glare stage, rising to a 10-microvolt peak in the glare state, and dropping back to almost threshold in the post-glare period.

These large remote effects of the visual sense operating on the involuntary level may have many consequences that cannot be discussed here; but they demonstrate clearly for our present purposes, the wide-spread ramification in the body of the effects of visual stimuli. In passing it may be remarked that they also raise a question about the application value of present data on the glare-comfort problem; namely, as the tension levels of the subjects used in "brightness-comfort-discomfort" (BCD) experiments were not measured, are engineers justified in applying the results in practice to people at large?

Returning to the subject of this paper, the preceding experiment illustrates, in one detail, the statement of Professor Herrick[8] that "all parts of the nervous system are bound together by connecting tracts (internuncial pathways). . . . These manifold connections are so elaborate that every part of the nervous system is in connection with every other part, directly or indirectly"; and one of the important involvements of the orientation reflex that can only be mentioned here is the triggering of the glandular system to support emergency action.

Dominance of Visual Sense

Summarizing the discussion to this point, visual energy enters the organism and initiates a chain of events. Nerve currents go to the thalamus and then branch out in a variety of directions. One of these directions is to the supra-granular layer of the cerebral cortex, and our concept of brightness is determined by the operation of this derivative of the original stimulus, as this is its only product that reaches a part of our organism where it can be consciously identified and evaluated.

The other, and probably major, products of the stimulus go to lower centers in the brain, such as those that operate the motor and regulating systems of the body, or that generate feelings. In short, when light enters the body it does a variety of things apart from communicating optical information about the environment. The most important thing it does is to operate our orientation system.

The visual sense is thus, in a very real way, a dominating factor in human life. On the voluntary level it is the principal means of contact and communication with the external world; and on the involuntary level it is the means by which the external world "push-buttons" people, so-to-speak, into what should be safe, survival-type reactions during their daily activities. The qualification "what should be" is inserted as there is now considerable evidence to show that in the complex world of twentieth century civilization, the operation of the orientation reflex is a factor in some individuals in generating chronic tensions that lead to ill-health as pointed out by D. B. Harmon in different context.[9]

It must be obvious from this discussion that the

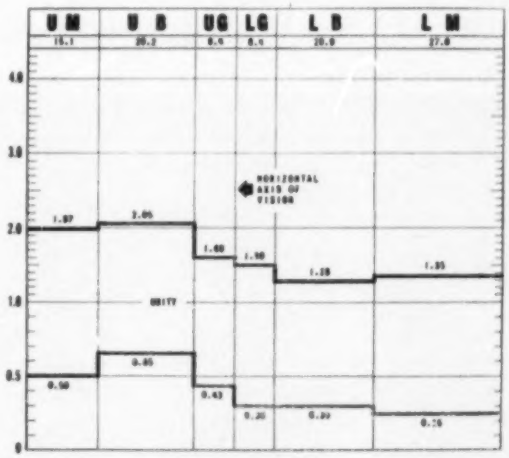


Figure 6. The two heavy lines that cross this diagram show the maximum relative quantity of light, and the minimum relative quantity of light to which normal people are fully adapted in their field of view as determined by investigations of the writer and reported in previous papers in ILLUMINATING ENGINEERING.[11]

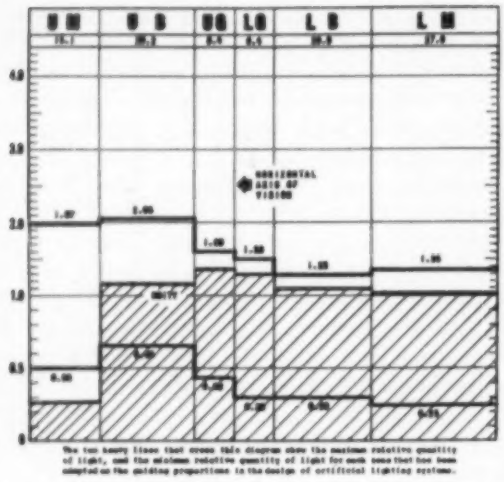


Figure 7. (above) Flux analysis of showroom in Fig. 8.

Figure 8. (right) Showroom analyzed in Fig. 7.

manner in which engineers light the external world not only affects the ease with which people communicate with it, but may affect their health, may contribute to keeping them free of injury or not, and may be a factor in determining whether they continue to live past a specific emergency or not.

These latter aspects of the effects of lighting have received small attention from engineers to date. The object of this paper is to emphasize the subject with engineers; to get them thinking about it, and hopefully to stimulate the kind of research that will develop the specific data needed to permit the design of scientifically safe and health-promoting visual environments. Only a beginning can be made here.

Inadequate Visual Clues

Work by H. Kluver (and others) seems to point to a basic principle that can be used in identifying existing or proposed environments which are likely to contain visual clues "inadequate to effectively trigger the orientation reflex." To quote Kluver,[10] "Brightness, area or distance of light sources are not effective in determining differential response. The various experiments point to the conclusion that only differences in density of luminous flux entering the eyes are effective." Kluver also concludes that, "The fact that the same photo-electric effect may be produced by an increase in brightness or an increase in area means, therefore, that the response is dependent on the luminous intensity of the stimulus"; that is, on the flux, and not on the brightness relations.

The Flux Diagram (Fig. 6) may therefore offer an initial means for a determination of light-connected accident potentialities in visual fields.

Since the body is an integrated apparatus and functions as an entity, it is a fair assumption that a lighting distribution to which people are well-adapted as determined in the manner discussed in previous papers,[11] will also alert them efficiently on the involuntary level. Examined from that point of view, lighting distributions that fall outside the guide lines of Fig. 6 can be suspected as potential accident breeders.

To illustrate: Fig. 7 shows the field of view distribution in the showroom pictured in Fig. 8. It is defective in the upper monocular portion of the field, which indicates the possibility that a hazard approaching the observer from that direction (or that the observer was approaching) would not give visual clues sufficiently above the threshold to trigger the orientation reflex.

It is important to note that this showroom interior, with its theoretically unsafe stimulus pattern, satisfies the present yardsticks for 100 per cent comfort response. It therefore does not follow that an environment that is visually comfortable on the voluntary level will generate either safe or health-promoting responses on the involuntary level. In fact, a lighting system that is optically comfortable by any of the yard-sticks we now use may nevertheless create an unsafe environment; and a system that is condemned by our present yard-sticks may effectively trigger the orientation reflex.

The possibility of an objective hazard connected with the upper monocular zone in this particular interior can be dismissed as too remote for consideration, although a subjective hazard remains

Figure 9. Heavy industry shop.

as a function of the distribution; but what of the heavy industry shop in Fig. 9? Here hazards are constantly present; from the moving crane in the upper monocular and other visual zones to the ground hazards in the lower zones. Lighting distributions that were defective in any of the visual zones could defeat the normal workings of the orientation reflex and result in repeated accidents.

Another aspect of this should be mentioned. The orientation reflex not only affects the orientation, posture and movement of the worker, but extends to the manner in which he handles tools and equipment. A large part of the cost of accidents is related to damage to equipment, machinery and material. The writer well remembers an incident during the recent war when a large machine was being readied for its trial run in the high bay section of a war plant. The costly controls were installed on the sides of the machine near the top and reached by an access gallery on the machine housing. The craneman had orders to move a heavy casting down the shop and past the huge machine. Both he and the hooker misjudged the clearance and the casting swung into the control mechanism. There was a stiff penalty clause for delay in delivery. The penalty, plus the cost of repairs and sequential uninsurable losses, totalled $40,000.

This type of orientation failure on the part of the craneman could have been avoided, with saving of the $40,000 loss if the kind of lighting study made after the accident had been made before. As it was the owners paid the $40,000 and the $9,000 cost of relighting.

Another type of inadequate visual clue is illustrated in Fig. 10. With the workman's eyes adapted to the light from his work his rod threshold is too high to permit the signals from the bar on the floor to trigger a protective reflex. If his path lay across the rod the possibility of an accident would be considerable. Some readers may feel that Fig. 10 represents a declining and insignificant aspect of modern industry. Its value lies in the fact that it shows an obvious situation, easy to visualize and discoverable upon a casual inspection. Similar accident possibilities exist in many interiors accepted by casual inspection as "well-lighted," because the principal factor involved is the often unobvious relationship of the rod threshold to the signals received.

An analysis of the flux distribution in an interior, in the design stage seems a sensible precaution to take against this type of accident breeder.

Shadow is an important agent in both raising and lowering the reflex adequacy of visual clues. The left half of Fig. 11 taken from Dr. Konrad

Figure 10. Rod lying on floor can hardly be noticed by direct inspection on the line of sight, and is obviously inadequate to initiate a safe reflex.

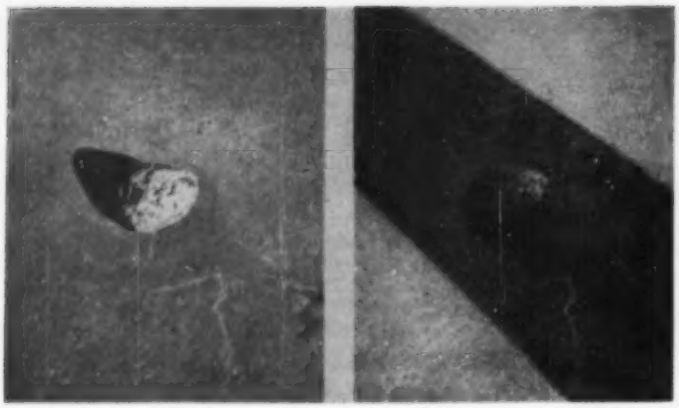


Figure 11. Illustrating the effect of revealing shadow overcast by distracting shadow. Taken from Dr. Konrad Norden's book "Shadow and Diffusion in Illuminating Engineering." Sir Isaac Pitman & Sons, Ltd., London.

Norden's book, "Shadow and Diffusion in Illuminating Engineering," shows an obstruction on a surface pointed up by its shadow. Both obstruction and surface are of similar color and material; and unless picked up directly on the line of sight (and so avoided voluntarily), the obstruction could not operate the orientation reflex if minus its shadow. Shadows can be effective in avoiding accidents, and their absence can be contributory to causing them. The right half of Fig. 11 shows still another situation in which a concealing shadow washes out a revealing shadow and so conceals the obstruction from everything except line-of-sight pick-up.

Misleading Visual Clues

Inadequate visual clues, for the purpose of this paper, are those arising out of greater than optimum differences in the stimulus from one or more zones of the visual field as compared with the distribution from the rest of the field. Misleading visual clues, on the other hand, will be considered as arising out of localized or adjacent differences. These, when obvious, are called shadows. Another difference is that inadequate visual clues usually fail to trigger an effective involuntary response, while misleading clues trigger the wrong response.

Optical illusions, although not infrequent in subtle forms, are excluded from consideration as they affect voluntary line-of-sight pick-up only. Color is excluded for another reason. While the presumption seems well established that the orientation reflex is operated by the intensity of the stimulus, rather than by its wavelength characteristics or color, there are numerous marginal situations in which the reflex is modified by habit "pre-sets" established by previous color experience. That this is important in the control of accidents is proved by the drop in accidents that invariably accompanies the use of scientific color treatment of equipment and space in hazardous occupations, such as mining. However, this phase of the subject is too complex for other than mention here.

Misleading visual clues, for the purposes of this paper, are therefore shadows present that should be absent; or shadows absent that should be present.

The left-hand picture in Fig. 12, also borrowed from Dr. Norden, is an example of the shadow present that should be absent. It is likely to trigger the wrong orientation reflex. The right-hand picture (b) is an example of the shadow absent that should be present. Its absence is also likely to trigger the wrong orientation reflex.

Examples could be multiplied but space forbids. A worthwhile research activity would be the identification and cataloging of frequently recurring situations of this type for the guidance of safety engineers.

Stimulus Level

A well-balanced visual field stimulus, properly proportioned within and between the various visual zones reduces accidents related to the orientation reflex. That the level of the stimulus also has an effect is obvious from traffic accident figures. Automobile accidents generally operate at a rate that can only be handled by the orientation reflex. The events are too swift for recognition and evaluation, then decision and action, via the will. During the daytime, accidents run uniformly lower than at night despite the heavier daytime traffic. The maximum difference is between starlight (blackout) conditions and full daylight conditions; which is seven to one. That is, the same region has seven times as many traffic accidents when only starlight is available than when full daylight is available. If this is prorated to take into account the heavier daytime traffic, the ratio becomes much higher. In short, daylight levels operate the orientation reflex

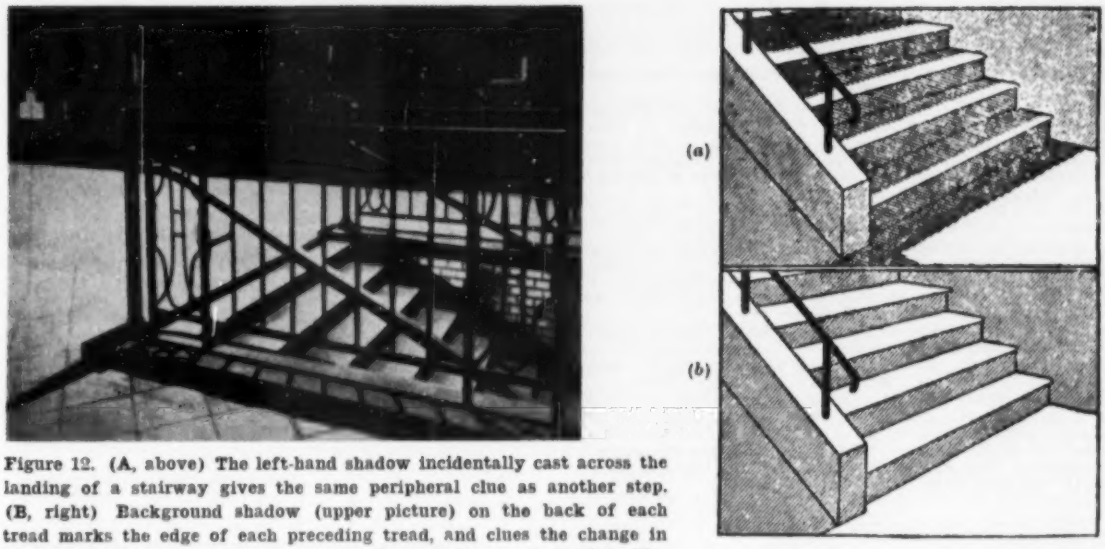


Figure 12. (A, above) The left-hand shadow incidentally cast across the landing of a stairway gives the same peripheral clue as another step. (B, right) Background shadow (upper picture) on the back of each tread marks the edge of each preceding tread, and clues the change in level between one tread and the next. Lower picture, shadowless illumination over whole tread wipes out the change-in-level clue. From Dr. Konrad Norden, "Shadow and Diffusion in Illuminating Engineering."

enormously more effectively, than do starlight levels. A research aimed at determining the stimulus level that favors most efficient reflex activity, with all its collateral effects on health, may show that the lighting levels required are higher than those needed for the line-of-sight function (*i.e.* "seeing") with the unexpected sequel that safety levels may have to be higher than those that can be economically justified for detail vision.

A statistical correlation of available data on accident rates and related lighting levels made by the author tends in this direction. The curve in Fig. 13 covers the region for which the data are available. If extrapolated, it would apparently level out in the neighborhood of 100 to 150 footcandles, indicating that value as a floor in interiors where irreducible hazards exist. This at present extremely tentative conclusion might not of course apply to school rooms, offices and similar interiors which are largely free of objective hazards. If extended to such interiors, it would probably have to be on the basis of subjective hazards that are outside the scope of this paper.

Concluding Remarks

Some phases of the subject have, of necessity, been omitted from this discussion; for example, the identification, operation and effect of subjective hazards; the effect on health and life expectancy of chronic muscular tensions, initiated or reinforced by the orientation reflex system; the growth of habit "pre-sets" that impair its safe operation, and the methods of cultivation of survival-type habit "pre-sets" with their color tie-in; and a detailed consideration of the effect of the orientation reflex on the handling of tools and equipment, have all been largely ignored.

Space has only permitted an introduction to a vast subject, but the author hopes that the operation of the reflex, with its dependence for safe action on specific lighting distributions in the field of view, has been sufficiently demonstrated. He has confidence that the ingenuity of engineers will permit them to apply the practical suggestions made in this paper to a wider variety of examples than the few that could be included.

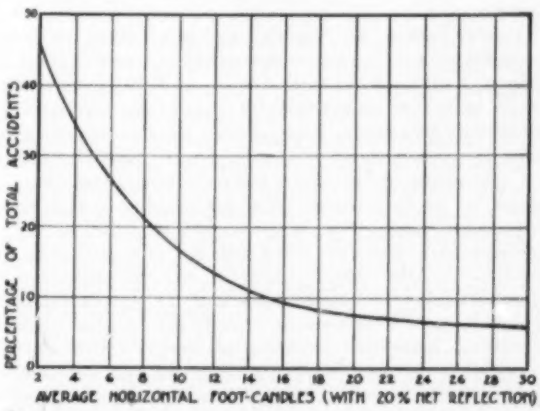


Figure 13. Accidents attributable to lighting causes shown as a percentage of total accidents over the principal part of the range in which lighting conditions are a cause.

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DISCUSSION

DOMINA EBERLE SPENCER*: As is his custom, Mr. Logan has presented an interesting paper on a phase of illuminating engineering that is often ignored. It would certainly be convenient if we could have a quantitative method of predicting the safety in a luminous environment. There are, however, several points in his discussion which I feel compelled to question.

Mr. Logan's paper seems to imply that safety has to do with rod vision. While it is true that rod vision is important for avoiding the trees on a starlit hike, it is doubtful if rod vision is a significant aid to safety even in night driving. And at the levels at which the illuminating engineer works, there is practically no variation in minimum perceptible contrast for rod vision (Fig. D-1). Over the entire range of illuminating engineering practice, the rod-curve is essentially constant. So if our safety depends on rod vision, all levels at which colors can be seen are equally safe. Mr. Logan's curve in Fig. 13, which indicates a marked decrease in accidents as cone vision is improved, contradicts his hypothesis of the significance of rod vision for safety. Over the range used in Fig. 13, from 10 to 150 lumen ft^{-2}, rod vision is unchanged. Only cone vision improves.

Another part of Mr. Logan's paper is based on the experiments of Klüver. Klüver performed an occipital lobectomy on a group of monkeys. That is, he removed the part of the brain that interprets visual stimuli. The eyes themselves were undamaged. Light entered the eyes and stimulated the visual receptors. Nerve impulses traveled along the optic nerve into the optic chiasma. Their normal destination in the back of the brain was missing, so that no sensation of light, vision, or space could be obtained. The monkeys were essentially blind but did give some slight reactions to light. Klüver attempted to study these reactions. He says,[1] ". . . the elimination of the geniculo-striate system leads to a complete or a practically complete elimination of visuo-spatial properties as effective determinants of behavior or, more briefly, to an elimination of visual space with its dimensions." In other words, these maltreated monkeys could not discriminate between the zones of Logan.

*University of Connecticut, Storrs, Conn.

1. Heinrich Klüver: "Visual Mechanisms," Biological Symposia VII, Jaques Cattell Press, Lancaster, Pa., 1942, p. 278.

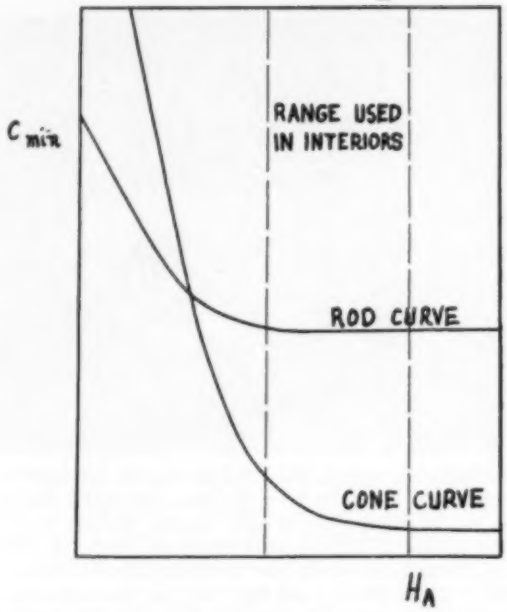


Figure D-1. Minimum perceptible contrast, C_{min}, versus adaptation helios, H_A. Both scales are logarithmic.

They could not focus their eyes; they could not even be said to have a line of vision.

What has this to do with human vision or even normal monkey vision? It certainly does not provide a bridge between reflex action and the Logan zonal fluxes. As usual, the infamous vivisection of monkeys has proved nothing. The zonal-flux method of Logan is no more significant for safe lighting of rooms than it is for quality lighting of rooms. It is true that many good and safe luminous environments will satisfy the Logan criteria. But it is also true that a sword might be suspended over Mr. Logan's head between two Logan spotlights and the sword might be invisible even though the zonal flux criteria were satisfied. This would not be a safe environment. In fact the sword might fall and render Mr. Logan a bilateral occipital human being. According to Klüver, he would then be able to perceive only luminous flux. But I certainly hope nothing like that ever happens to my good friend, Mr. Logan.

H. L. LOGAN*: The serious part of Dr. Spencer's discussion concerns two points: one, that rod vision has nothing to do with safety; and two, that the work of Klüver, cited by the author, does not prove the deep-seated character of the orientation reflex.

The first point is immaterial, and the second is mistaken. With reference to the first, it makes no difference in what proportion the rods and cones act as a part of the reflex sequence. The fact is the reflex sequence takes place, and is initiated by luminous radiation striking the peripheral area of the retina. The author is of the opinion that the rods play a large part in this and deplores the paucity of data on their action under photopic conditions. A knowledge of exactly what part the rods play would add to our understanding of the orientation reflex, but would not affect the fact of the orientation reflex nor its importance in safety.

Dr. Spencer's second point relates to the author's state-

*Author.

ment that the "roots" of the orientation reflex go back in the evolutionary sense to the earliest and most rudimentary moving life forms; and hence that the reflex is, so-to-speak, built into the basic nervous organization of moving forms of life. In order to show that this basic situation persisted in forms of life almost as complex as man, the author cited Klüver's experiment. When Dr. Spencer says that the eyes of the monkeys were undamaged in the experiments but that although the *normal* destination of the nerve impulses in the brain was missing, the monkeys still reacted to light, she is simply confirming the point the author was making.

The fact that the monkeys "could not focus their eyes" and did not "have a line of vision" is evidence that their reaction to light was a peripheral function. The orientation reflex does not depend upon the imaging facility, which is a property confined to the neighborhood of the line of sight.

People who lose foveal vision (line-of-sight facility) retain their orientation reflex intact as long as the damage does not extend into peripheral areas, but people with extensive hemorrhages in the peripheral areas of the retina (one of the frequent consequences of chronic high blood pressure) find their orientation reflex impaired or even lacking. If they drive a car they are, for example, in constant danger of encountering side collisions from other cars coming in from intersections.

To make this clearer, let the reader take a pair of plain glasses and paint them black, except for a little space in the center of each plain lens that is large enough to illuminate the foveal region of the retina. The reader will be able to read as well as ever and be able to do any fine close work just the same as before, but he won't be able to move around safely without the aid of a seeing-eye dog. People who are permanently in this state meet the legal qualifications of the blind and are entitled to all the public aids provided for the blind. Yet they can "see" as well as anyone. They have not lost their line-of-sight facility, their ability to form optical images, nor their ability to see detail.

On the other hand, if the reader will block that same part of the eye and let in light from the remaining 99 per cent of the field of view, he will be unable to read or do any close work, but will not need be legally blind, nor need any aid in getting around as his orientation reflex will be unimpaired. It is doubtful if among pre-historic primitives, individuals so handicapped would ever realize it, as it would not interfere with their objective orientation. They would be just as safe in moving around as anyone else without benefit of the function of visual acuity, upon which Dr. Spencer's theses are reared.

Interflectance Tables from Conventional Photometric Data

Discussion on paper by LESLIE E. INNIS

(Published November issue of ILLUMINATING ENGINEERING)

J. J. NEIDHART*: The crux of my remarks on this excellent paper may be found in a statement made by Mr. Innis near the end of his paper. In this statement, he says that it is possible to construct tables for other distribution patterns by utilizing other powers of the cosine θ, and "this suggests the possibility of eventually establishing interflection tables for all luminaires; however, further work will be necessary in order to determine whether such a possibility can become a reality." Interspersed through the paper other statements may be found referring to the possibility of providing additional tables to match distributions not covered. We can only wonder how many additional tables will be required and whether the system will retain its simplicity when it is made all-inclusive. Any attempt to limit the number of tables required must be carefully weighed against the resulting sacrifices in accuracy.

In many respects, this method of obtaining coefficients of utilization is similar to the Zonal Factor Interflectance Method introduced by Roy Jones and me. Both methods utilize the Interflectance Method, and both methods have similar objectives — *i.e.*, to use conventional photometric data, to include data for current ceiling, wall and floor reflectances, to employ a properly located work plane, and to obtain coefficients of utilization that could be used in the familiar Lumen Method. Both systems permit the calculation of average ceiling, wall and floor brightness. They differ only in approach and in the concept of Room Index. In this latter respect, it should be mentioned that Mr. Innis' objections to the letter indices can and will be overcome by using the numerical room ratios for which these letters stand. Mr. Allphin has also published a chart similar to the one referred to by Mr. Innis except that it yields room ratios as an end product.

We can take advantage of another similarity as a means of checking the validity of Mr. Innis' assumption that coefficients of utilization for a wide variety of luminaires can be calculated by merely multiplying the efficiency of each luminaire by appropriate interflectance factors selected from a few representative tables. If Mr. Innis' premise is correct, we should be able to obtain the coefficients of utilization for any given luminaire by multiplying the Zonal

*Westinghouse Electric Corp., Lighting Division, Cleveland, Ohio.

Method calculated coefficients for another luminaire *having a similar distribution* by the ratios of the efficiencies of the two luminaires. When this procedure was applied to two-lamp troffers having similar candlepower distribution curves but different efficiencies (due to different types of shielding) it was found that maximum error that could be incurred was approximately 5 per cent. However, when I attempted to apply the technique to aluminum high bay luminaires having narrow or medium distributions, I found that distribution curves that appeared to be sufficiently similar to permit use of the efficiency ratioing technique actually had small differences that resulted in errors as high as 20 per cent in the high narrow rooms in which such luminaires are likely to be applied. This error gradually diminishes as the room size increases.

It is thus apparent that Mr. Innis' method of obtaining coefficients of utilization has a basic weakness in that it depends upon the discretion and judgment of a person using the method in selecting the proper table to match the distribution of the luminaire for which coefficients are to be calculated. Furthermore, when the tables are expanded to include all of the necessary prototype distributions and probable mounting heights, the problem of selecting the proper table out of the large number of tables will be increased.

ANSON H. RUSSELL*: We are glad to see that Mr. Innis has brought to the attention of the Conference Moon and Spencer's method of Interflectance Calculations for various luminaires, published previously in the *Journal of the Franklin Institute*. He has extended the work to include interflectance or utilization factor data tabulated for certain combined distributions.

It is of interest that results obtained mathematically have been corrected upward to values for some systems of discrete units as indicated by measurements. It is our opinion that utilization data should and will include information for both individual and continuous units of a variety of distributions. Mr. Innis' paper is limited to distributions which are approximately cosine. Even the four idealized direct distributions covered in Moon and Spencer's original paper hardly seem adequate for all concentrations of direct components. The direct ratios for adjacent types sometimes differ substantially. Perhaps others can be added.

As for the upward components, Mr. Innis concludes that distribution curve shape is not very critical. He appears to have based this conclusion upon utilization factor values derived from data in Table 9-15 in the *I.E.S. Lighting Handbook*. This is a table of coefficients of utilization including the three indirect curves shown by Mr. Innis. By dividing the coefficients of utilization by efficiency, the same utilization factors are obtained. This is, of course, the case, since Harrison-Anderson tables, on which these are based, include but one factor to cover all indirect distributions. Our experience indicates that some difference is to be expected with different indirect components.

L. E. INNIS**: In the broad sense described by Mr. Neidhart, there is indeed a certain similarity between this method and the Zonal Interflection Method. From an overall viewpoint, however, I believe that a stronger similarity exists between the method described in my paper and an earlier approach described by Coradeschi and Innis[1] despite the fact that the latter does not utilize conventional photometric data.

In connection with the concept of Room Index, an effort was made in the body of the paper to stress the ingenuity of Mr. Allphin's approach[2] by referring to "numerical indices" which include both the Hisano index and room ratios. Evidently this point needed to be accentuated. I believe Mr. Neidhart has accomplished this by again mentioning the flexibility of Mr. Allphin's work.

The tables given in this paper, as explained, pertain to the widespread type of distribution. Happily, many of our modern luminaires are of this type. As stated in the paper, further work is necessary to extend this method to narrower distributions and to determine whether such a method will provide universal coverage. As far as I know, this work has yet to be done. Until it is, it seems rather pointless to discuss number of tables required, simplification of data or even "basic weaknesses." In this respect, I would like to point out that Mr. Neidhart's "basic weakness" exists only if one assumes that the criteria for choosing the appropriate table would be a visual one. This need not necessarily be the case.

In reply to Mr. Russell's remarks on the indirect distribution, the conclusion drawn from Fig. 8 was not that all indirect distributions give identical results, but rather that a greater deviation from the idealized curve is allowable in the upper hemisphere than in the lower hemisphere. Potter and Russell[3] in their recent paper have shown some difference between different indirect distributions. This difference does not, however, appear to be appreciable even for the critical case of the small room. From an overall practical viewpoint, I am convinced that the above conclusion is absolutely sound.

1. Coradeschi, P. A., and Innis, L. E.: "An Application of the Interflection Theory to Commercial Practice," ILLUMINATING ENGINEERING, Vol. XLIII, p. 949 (November 1948).

2. Allphin, W.: "Numerical Room Ratios," ILLUMINATING ENGINEERING, Vol. XLVIII, p. 206 (April 1953).

3. Potter, W. M., and Russell, A. H.: "Measured Utilization Factors," to be published.

*General Electric Co., Nela Park, Cleveland, Ohio.

**Author. Sylvania Electric Products, Inc., Salem, Mass.

Packaging Room at the New Mennon Company Plant, in Morristown, N. J.

Features . . . .

Continuous Wall-Ceiling Lighting In an Industrial Plant

THAT'S a factory? It's an industrial area, circa 1953, built by the Mennon Company at Morristown, New Jersey, for the manufacture of their products. The photograph above is of the packaging department, where electric lighting and daylighting have been engineered to blend in comfortable proportion.

In this ceiling-to-wall-to-floor combination, a louvered ceiling provides overall area illumination; functional glass block extends similar brightness patterns over the entire side wall, floor to ceiling. All surfaces, including machinery, contribute to the desirable brightness balance. Comfort at 50 footcandles maintained is the result.

For such a large luminous ceiling area (19,200 square feet mounted at 12 feet 6 inches) monotony has been avoided with a planned arrangement of acoustical tile and rows of low-brightness louvers of a pleasing green color. All utilities and sprinklers are, of course, entirely concealed.

Luminaires used are 16 feet by 8 feet, using 96-inch slimline lamps mounted 32 inches on center. The white metal egg-crate louvers are in 4-foot by 2-foot panels, and provide 45/45 shielding. Servicing is performed by releasing any of the louver-panels, which hinge from either side or can be removed completely for cleaning.

Contributing to the effectiveness of the lighting system, and blending into the luminous ceiling, is the outside wall, constructed with a specified proportion of two types of functional glass block. In the huge floor-to-ceiling panels, a pattern has been used in which light-*directing* glass block (directing light upward) was installed above eye level, while light-*diffusing* glass block is used below eye level, diffusing light to floors and walls. A high order of visual comfort is achieved with this carefully planned ceiling-wall partnership.

Architects for the entire Mennon plant, of which only one room is here described, were A. M. Kinney Associates, Cincinnati, Ohio. Electrical contractor was Edward J. White Company, Newark, New Jersey.

Data supplied by Smithcraft Lighting Division, Chelsea, Mass., and Pittsburgh Corning Corp., Pittsburgh, Pa. Picture from Edward J. White Co., electrical Contractor, Newark, N. J.

Mercury Lamp Starting Requirements For Outdoor Applications

By A. E. BINDER

MERCURY lamps are presently used outdoors in many cold weather locations, but the starting voltage requirements have not been well established. Colder weather requires higher voltages to start mercury vapor lamps, similar to fluorescent and other types of mercury vapor lamps.

Certain voltages have come into common use for outdoor installations. The H400-A1 and B1 lamps (400-watt glass arc tube) have used 230 volts, the H400-E1, J1, R1, and RC1 lamps (400-watt quartz arc tube) have used 300 volts, and the H250-A5 lamps (250-watt quartz arc tube) have used 275 volts. No special voltage has been used for the H1000-A15 and C15 lamps (1000-watt, 460-volt open circuit), because starting is reliable down to about 0°F with 460 volts. Although there is not complete agreement among lamp manufacturers on these voltages, they have been recognized as being the minimum voltage for satisfactory starting outdoors. It is usually stated that these voltages provide reliable starting down to some minimum temperature, −20° or −30°F.

No statistical data could be found in the literature relating the starting of different types of mercury lamps at low temperatures with various open circuit voltages. For H400-E1 lamps, Burns, Freeman, and Rowten have shown a graph of open circuit voltage required for reliable starting at various temperatures,[1] but do not show the statistics on which the curve is based. In order to determine more accurately ballast open circuit voltages required for starting in cold weather, it is necessary to know both the statistical variation of starting voltages with temperature and the frequency of occurrence of the coldest temperatures to which mercury lamps will be subjected.

Satisfactory starting at low temperatures involves two parts. First, the open circuit voltage must be great enough to strike the arc. Secondly, the lamp must warm up within a short time to the point where all the mercury is evaporated and the lamp is delivering full output. This paper is concerned only with the voltages necessary to initiate the arc. All lamps tested here warmed up to full brightness at all temperatures when operated on a lag circuit.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 14-17, 1953, New York, N. Y. AUTHOR: General Electric Co., Lamp Development Laboratory, Cleveland, Ohio.

Lamp Starting Voltages

In the early part of the investigation, the voltages necessary for starting lamps at various temperatures were determined in the manner that has been customary in the past. The primary voltage of commercial type lag ballasts was gradually increased by means of a Variac until the lamp started. Maximum secondary voltage attained before starting was recorded as the starting voltage of the lamp. These measurements were made at each of four temperatures: 32°, 0°, −15°, and −30°F. Large numbers of lamps were selected from as wide a period of manufacturing dates with as many different hours of burning as possible.

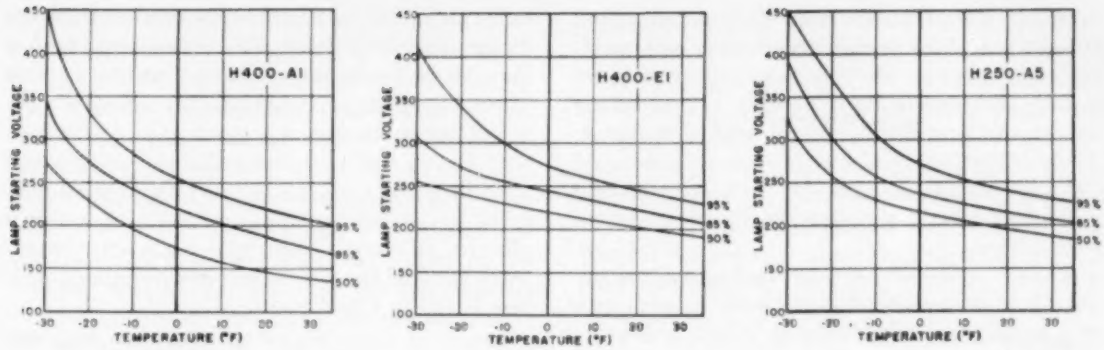
The effect of temperature on starting voltages is shown in Fig. 1 for each of the four sizes of arc tubes covered in this paper. Lamps of common arc tube design do not all have identical starting voltages, but rather show a statistical variation. Voltages required to start 50 per cent, 85 per cent, and 95 per cent of the lamps are displayed as a function of temperature. The number of starts at each temperature were 96 for the H400-A1, 200 for the H400-E1, 60 for the H250-A5, and 112 for the H1000-A15.

Probably the most interesting observation from these data is the rapid increase in starting voltage as the temperature is lowered. This is shown in Table I which gives rate of increase of starting voltage per degree Fahrenheit drop in each of the three temperature ranges measured.

With the rapid rate of change of voltage required for starting with temperature, it is not easy to select a voltage which will give satisfactory starting at low temperatures without actually

TABLE I.—Approximate Average Rate of Rise of Starting Volts (Volts/°F).

Lamp Type	32° to 0°F	0° to −15°F	−15° to −30°F
H400-A1	1½	3	6
H400-E1	1	2	5
H250-A5	1	3	8
H1000-A15	4	7	12



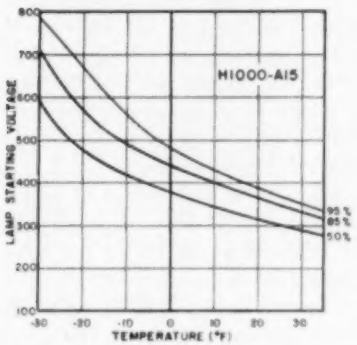


Figure 1. Statistical variation of lamp starting voltages at various ambient temperatures.

1a. (above left) H400-A1 lamp.

1b. (above center) H400-E1 lamp.

1c. (above right) H250-A5 lamp.

1d. (left) H1000-A15 lamp.

knowing minimum temperatures likely to be encountered. A difference of 5°F in selection of a design temperature in the coldest range would require an additional 40 volts for a ballast to start H400-A1 lamps. Forty volts represents too large a ballast design factor to permit a guess as to minimum temperatures encountered. Excessively large ballasts result if voltages are specified for starting down to the lowest temperatures measured here.

Climate Characteristics

Temperatures in certain portions of this country dip to −40°F or lower on occasion almost every year. Other portions of the country experience little weather below freezing. Obviously the warmer climates will not require as large a ballast as the colder areas. Equally obviously, it would be impractical for ballast manufacturers to tailor-make ballasts for each winter climatic condition.

At −30°F, the commonly used ballast voltages mentioned in the opening section, start only a small fraction of the total lamps (for example only 15 per cent of the H400-A1 lamps, which has been the most commonly used lamp in the past). The author has been unable to learn of any reports of non-starting of present installations in even the coldest areas. Many installations have been in operation a number of years, experiencing extremes of cold weather. It was suspected that temperatures at the time of starting seldom, if ever, reach as low as −30°F in any location using mercury lamps. A better knowledge of temperatures to be experienced in these coldest areas is required in order to specify open circuit voltages needed under the most severe conditions, and to correlate field experience with laboratory data.

The most convenient sources of temperature data have been located in articles published in the home design and heating fields. These data have been derived from U. S. Weather Bureau data for cities all over the United States and for a period of many years. A survey made by The American Institute of Architects and *House Beautiful* magazine[2] shows the frequency variation of temperatures in each month in a number of locations in the United States. In this survey, design temperatures for heating requirements are recommended. This design temperature is not the minimum temperature encountered in these locations, since extreme temperatures occur infrequently and are of short duration. Several references[3, 4, 5] listed in this survey give temperature data in 120 cities, and the basis of selecting a heating design temperature from these data. A design temperature at which mercury lamps must start can be derived from the same data; however, it will be different in value.

Heating design temperatures are generally based on minimum *mean* daily temperatures, rather than

minimum temperatures. Mean daily temperatures are also useful for specifying mercury lamp starting temperatures. Mercury lamps are turned on in late afternoon or early evening, a time of the day at which temperatures are near a maximum. Temperatures at this time of day are above the mean temperature for that day, usually by at least 5°F. This greatly aids starting, especially on the coldest days.

A table in one of the references[3] shows the frequency of occurrence of daily mean temperatures of a certain degree or colder, in locations throughout the United States. The coldest of these locations recorded was Devil's Lake, North Dakota. Over a period of 23 years, on an average of five times a year, the mean daily temperature dropped to −19°F or lower, and on an average of once a year the temperature dropped to −26°F.

A separate set of tables of data from the U. S. Weather Bureau[6] shows the frequency of occurrence of *hourly* temperatures in 117 locations of the United States from 1935-1939. In this five-year period, the temperature at the time of starting fell to −15°F or lower on 23 days, and to −20°F or lower on four days in this same area. Compared with the frequency of occurrence of daily mean temperatures, this illustrates that the temperature at the time of starting is about 5°F warmer than the average temperature for the day. This also shows that there is no need for the voltage to be any greater than that which will satisfactorily start lamps at −15°F. Even in the coldest area of this country, the temperature drops below this value only occasionally.

Observations on Starting

Consider a design temperature of −15°F at which mercury lamps must start. At this temperature with presently used outdoor open circuit voltages, starting is achieved in only 70 per cent of the H400-A1 lamps, 90 per cent of the H400-E1 lamps, and 85 per cent of the H250-A5 lamps. The H1000-A15 lamp has no voltage recommended for starting, but 460 volts will start about 65 per cent of the lamps.

Seventy per cent of the lamps starting, as in the case of H400-A1 lamps, is not satisfactory by any standard. Even though measurements taken in the Laboratory would indicate poor starting performance at these temperatures and voltages, the author has learned of no complaints from field installations regarding non-starting.

During the measurements on starting, it was suspected that the laboratory method of measuring starting voltages gave different results than would result in actual installations. Yet it was difficult to measure or estimate the differences. It was thought that switching transients at the moment of starting might be responsible for a greater number of lamps starting at a given open circuit voltage. It had also been observed that a lamp would start at a voltage slightly lower than those measured as the starting voltage, if sufficient time was allowed. In order to determine the relative importance of these two effects, a special starting circuit was set up in a cold room.

Lamps at a certain temperature were subjected to a certain open circuit voltage applied by closing a relay in the primary circuit of the ballast. If the lamp started and warmed up within one-half hour, it was counted as having started satisfactorily. Cycling of the group of lamps was arranged so that lamps were warmed up and thoroughly cooled again to ambient temperatures before a successive start was made. The percentage of lamps starting under these conditions was compared with the percentage of lamps starting under the same voltage and temperature conditions in the earlier tests. Testing was largely confined to an H-1 ballast set at 220 volts open circuit and with the lamps at an ambient temperature of −15°F.

At −15°F, few of the H400-E1 lamps started as soon as the relay closed. Most lamps started, not immediately, but after a wait of from a few seconds to ten minutes. Starting eventually took place on a very large number of lamps, a much greater percentage than shown in Fig. 16. Starting was not preceded by a glow or low current discharge, so that low current heating of the electrodes was not a factor in aiding starting. Since few of the lamps started when the primary circuit was closed, switching transients were not a factor aiding starting. Starting voltage of lamps is not an absolute quantity, but is affected by the time allowed to start.

Measurements were made at −15°F with the secondary voltage of an H400-E1 ballast set at 220 volts. It was necessary to use these conditions to get enough lamps to *not* start, in order to compare with the earlier measurements. With a large number of lamps under these conditions, 87 per cent starting was achieved. Only 23 per cent of the lamps would be expected to start instantly, as originally measured. To start 87 per cent of the lamps instantly, 255 volts is required. Individual lamps with starting voltages measuring as high as 255 volts would start at 220 volts practically every time within one-half hour. If some time delay in starting is permitted, H400-E1 lamps will start at voltages as much as 35 volts lower than those mea-

sured by conventional laboratory methods. This differential in starting voltages has not been determined for the other sizes of lamps reported here.

It is much more desirable that a lamp start as soon as it is turned on than to wait. Measurements shown in Fig. 1, if used to specify ballast open circuit voltages, will ensure instant starting. Since lamps will start at lower voltages (or at colder temperatures) after a short time delay, open circuit voltages need be specified only for temperatures somewhat above the actual minimums encountered. On the rare occasions that colder temperatures exist, lamps will still start, but after some time delay. In this manner reliable starting can be assured with lower open circuit voltages than have been specified in the past.

While the above discussion relates lamp starting characteristics with the most severe climates in this country, a further analysis will show that voltages commonly used in indoor installations are wholly satisfactory throughout a large section of the United States. Voltages used with indoor ballasts will start lamps instantly down to a certain temperature, depending on lamp and ballast. These temperatures can be taken as those at which 95 per cent of the lamps will start instantly at the given voltage. This is 13°F for the H400-A1 lamp, 32°F for the H400-E1 lamps, 10°F for the H250-A5, and 2°F for the H1000-A15. Since the temperature at the time of starting is usually at least 5°F warmer than the mean temperature for the day, indoor voltages are good in locations where the daily mean temperatures seldom (once a year or less) drop below 8°F for the H400-A1 lamps, 27°F for the H400-E1 lamps, 5°F for the H250-A5 lamps, and −3°F for the H1000-A15 lamps. As in the coldest locations using higher voltages, there may be a short time delay in the starting of some lamps on the coldest days. Since the time delay is at the most a few minutes, it may never be noticed in most places.

Other Factors Affecting Open Circuit Voltage Requirements

The voltage required to start H400-A1 lamps is less than that required to start H400-E1 lamps at all temperatures at which they will be used. At a temperature between −20° and −25°F, the starting voltages become approximately equal. Because the lamps are electrically interchangeable, it is desirable to have only one ballast. The higher starting voltage of the H400-E1 lamp is recommended as the voltage to be used for H-1 ballasts.

Open circuit voltages must also be sufficient to enable the arc to restrike every half-cycle. Even a momentary dip to a voltage below this will extinguish the arc. The open circuit voltages now used in indoor ballasts are as low as can be used to ensure arc stability. These voltages are 230 volts for the H-1 ballast, 250 volts for the H-5 ballast, and 460 volts for the H-15 ballast. Any recommended voltages for starting must be at least as high as these voltages.

Summary

In very few locations in this country, and only on a few days of the year in even these locations, does the temperature fall below −15°F at the time at which mercury lamps would be started outdoors. Because of the infrequency of even this temperature and because more lamps will start in time at this temperature than is indicated by the data in Fig. 1, a voltage which will start 85 per cent of the lamps at −15°F, will be sufficient to give reliable starting under all conditions of operation. For the H400-E1 lamp, this voltage will actually start about 93 per cent of the lamps.

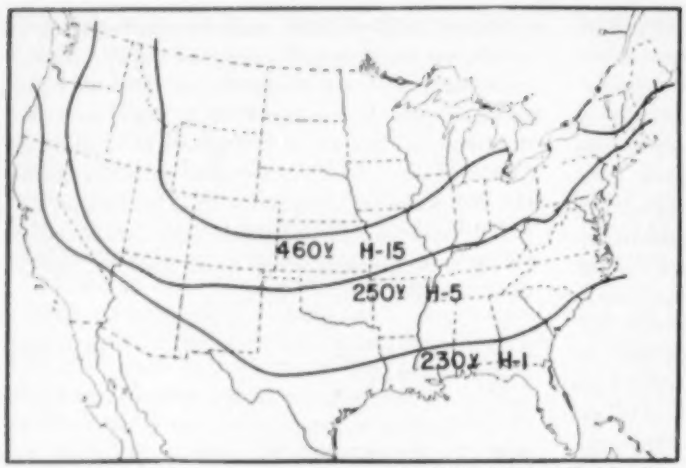
Voltages which will instantly start 85 per cent of the lamps at −15°F are respectively:

H400-A1	255 volts
H400-E1	260 volts
H250-A5	275 volts
H1000-A15	520 volts

It is desirable to specify the same voltage for both the H400-A1 and E1 types of lamps, which would lead to a recommended starting voltage of 260 volts for both lamps outdoors.

In more southerly and coastal locations, the voltages used indoors are sufficient to start lamps outdoors. The same type of analysis was used to determine the location at which these voltages are satisfactory. For simplicity, these areas are shown on an outline map of the United States (Fig. 2). The indoor ballast voltages shown (230 volts for H-1 ballasts, 250 volts for H-5 ballasts, and 460 volts for H-15 ballasts) may be used satisfactorily as far north as the respective lines indicate. In these areas, on an average of once a year or less, the temperature at the time of starting falls below that at which 95 per cent of the lamps will start instantly. Ballasts exposed to outdoor weather must, of course, be weather-proofed.

Lamps start more easily and temperature conditions are not as severe as has been assumed in the past. Previously recommended voltages for outdoor installations are higher than need be, espe-



Copyright, American Map Co., Inc.

Figure 1. Voltages used for indoor ballasts may be used satisfactorily outdoors as far north as shown by respective lines. Higher voltages should be used north of these lines.

cially for H400-E1 type lamp. Voltages used at present only for indoor ballasts may also be used for outdoor ballasts in more locations than previously considered possible. In addition, voltages have been recommended for outdoor use of H1000-A15 type lamps, for which no voltage has been recommended up to the present time.

It is hoped that the investigations reported here will serve as a basis for industry wide standardization of ballast open circuit voltage for both indoor and outdoor use.

Acknowledgments

I wish to acknowledge the assistance of Miss Janet Henchie and Mr. Ralph Vichill in the preparation of data for this paper.

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DISCUSSION

G. A. FREEMAN*: In a quick perusal of the paper one gets the impression from the curves, and particularly the marked off map of the United States, that the author would not recommend mercury lamps for outdoor use in many parts of the United States. The curves are considerably different from those used by Westinghouse which have been checked over quite a number of years in the laboratory and with field observations.

In reading the paper more carefully the opposite impression is created, that mercury lamps will give satisfactory performance at low temperatures. The author had difficulty reconciling the poor low temperature performance indicated by his laboratory data and the absence of complaints from the field where there are numerous mercury lamp installations in places noted for low winter temperatures.

A drawing has been prepared on the same four lamps to show curves which have been previously developed and used as a basis for the ballast voltages that are in common use today. These curves are for 100 per cent starting of all lamps and include data on new, unseasoned lamps and lamps at various stages during life. Curves for practical use would be somewhat lower because unseasoned lamps would not have to be provided for. If the curves in Fig. 1 of the paper are compared with this drawing at the —30F

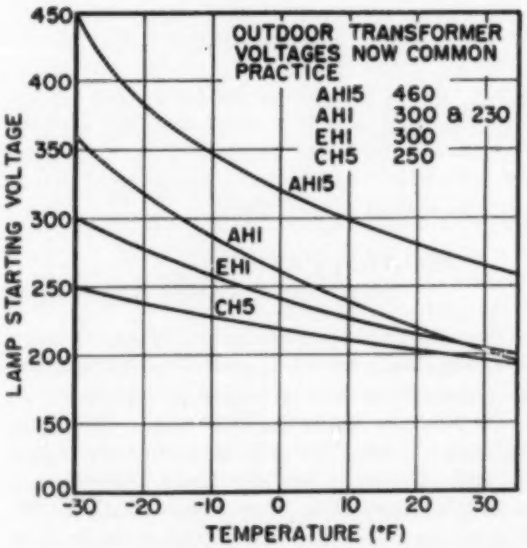

Figure D-1. Voltage for instant starting 100 per cent of mercury lamps at various ambient temperatures.

*Westinghouse Electric Corp., Bloomfield, N. J.

point, large differences will be seen. The A-H15 takes 400 volts at —30F but Fig. 1 shows 780 volts to be necessary. The E-H1 takes 300 volts and Fig. 1 shows 410. The A-H1 takes 360 volts and Fig. 1 shows 450. The C-H5 takes 250 volts and Fig. 1 shows 450.

Three suggestions that may account for the differences are:

1. Restarting a lamp which has just been flashed on and off will often require higher voltage on the second try. The proper procedure is to operate the lamp for a few minutes up to its full output before putting it back at low temperature for another test.

2. The author mentions the effect of time in getting lamps to start at lower voltage. In the laboratory he may have allowed too little time for each test by applying voltage only momentarily. The laboratory procedure regularly used is to bring voltage up slowly over perhaps 30 seconds until lamp ignition occurs. Certainly a street lighting installation will be considered satisfactory if lamps start within 30 seconds.

3. Design differences of lamps from different manufacturers might have some effect.

The drawing also shows the outdoor transformer voltages that are now in use. Fig. 1, and particularly Fig. 2 of the paper, lead one to believe that the transformer voltages now used in outdoor installations in all parts of the United States are too low. It is not easy for the reader to reconcile that impression with the statement in the summary that "Previously recommended voltages for outdoor installations are higher than need be especially for the H400-E1 type lamp."

It is recommended that further investigation be made by the author to explain the apparent discrepancy between his curves and field experience before any changes are made in the recommended open circuit voltages.

W. S. Till*: The author is to be congratulated for his investigation of the subject. My comments may be summarized as follows:

1. Our field reports show that there is no problem of cold weather starting with present outdoor type mercury ballasts.

2. Indications are that a voltage of less than 300 volts may now be sufficient to start the 400-watt A-H1 and E-H1 lamps in cold weather. Experience with E-H1 lamps operated on the present 300-volt ballasts is so good that no change would seem desirable until proven acceptable by actual service tests.

3. The 250-watt C-H5 starts satisfactorily with 250 volts. There seems no need to raise this value to 275 volts

4. Industry wide standardization of ballast open circuit voltage and other characteristics is certainly desirable.

Considering the lamp types individually, we have record of more than 3000 400-watt quartz E-H1 mercury lamps in street lighting service in the two coldest states — North Dakota and Minnesota. There have been no starting difficulties, despite occasional 50 below zero weather during the past five winters. We do not know exactly what the temperatures were at the time the lamps were turned on but it seems safe to assume that they were sometimes well below zero.

Now with regard to 400-watt A-H1 glass type mercury lamps, the City of Denver alone has several thousand, most of which operate from ballasts that furnish only 220 volts. Denver's winter temperatures occasionally reach well below zero, and there have been instances of lamps not starting because of the cold, but there were only a very few such occasions.

Mr. Binder's suggestion, that there be one recommended starting voltage for E-H1 lamps for outdoor applications, is commendable, as this permits interchangeability. There is some doubt as to whether the starting voltage should be 260 volts, as he suggested, or 220 volts or 300 volts. Since the present curves indicate that the A-H1 is approximately as hard to start at cold temperatures as the E-H1, it must be puzzling to many that a starting voltage of 220 has been satisfactory for the A-H1, but not used outdoors for the E-H1. However, results have been so good with 300-volt ballasts that it would seem desirable not to throw away this margin of safety without first obtaining some field experience in a very cold area, possibly with 220 starting volts as well as 260. Laboratory tests may not be sufficient in deciding a matter of this sort.

In reference to the 250-watt H-5 lamp, no starting difficulty has ever been reported to our knowledge, and there is apparently no reason to change from 250 to 275 volts as suggested by Mr. Binder. C-H5 lamps have operated very satisfactorily for 13 years in over 1000 sockets in the tunnels of the Pennsylvania Turnpike. In addition there are many good C-H5 installations throughout the middle west and in the northern states.

In regard to the H-15 lamp, there are as yet very few outdoor installations, so no comment is offered.

F. D. Wyatt*: It is very encouraging to see this study by Mr. Binder on the characteristics of transformer ballasts for mercury lamps. With the great number of mercury lamps now in service and the large additional number of mercury installations going in, it is very desirable that the greatest possible information can be secured on the characteristics of the lamps and ballasts under various climatic conditions.

I assume that in Mr. Binder's paper he is referring throughout to rms sine wave voltages. I would like to call attention to the fact that the secondary or lamp voltage from most ballast transformers is not a sine wave and may have sharp peaks of over voltage which may assist in firing the lamp. There is reason to believe that relatively short time crest voltages will flash over the lamp and that after several such flashovers the starting voltage is reduced. It would appear, therefore, that the non-sinusoidal wave of the lamp voltage should receive consideration in rating the secondary voltage of the mercury ballast transformer.

It is entirely possible that the most effective rating information for these mercury ballasts would be based on crest voltage rather than rms sine voltages. The form factor and crest factor may be of importance in the discussion of mercury lamps. It is suggested therefore to the author that this characteristic of mercury ballast transformers be further considered.

It may be economical to design a transformer which extenuates the wave shape distortion in order to improve the starting characteristics of the lamp, provided that it is found that the distorted wave shape does not adversely affect the life of the lamp.

There are now available good multiple ballasts which provide very reasonable cost in the overall economic picture involving the ballast and the distribution circuits. There is, however, a great need for improvement in the prevailing designs of series individual lamp transformers to supply mercury lamps.

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*Chicago Park District, 425 E. 14th Blvd., Chicago, Ill.

H. U. Hjermstad*: I have the feeling after hearing Mr. Binder's paper and looking at some of the data that a great number of these lamps should never have started.

I cannot agree with him that the open circuit voltages of ballasts be reduced until such time as the mercury lamps are brought into closer manufacturing tolerance. Just three years ago, in order to insure positive starting of the E-H1 lamp, we raised the open circuit voltage on our present ballast from 300 to 350 volts.

It is interesting to note that on a recent group of lamps that were tested, the normal arc drop in the lamp varied between 102 and 153 volts. I understand that the present manufacturing tolerances are 120 to 150 volts with 135 volts as a design center.

No mention has been made of the starting voltages and variations of the lamps tested and no indication has been given of the normal arc drop of these lamps and the wattages developed at the various temperatures. I agree that we are paying quite a penalty for the extra VA that is required to assure starting lamps; perhaps it might be possible to provide auxiliary heating to the cathode for cold weather applications and thereby reduce the necessary open circuit voltage and VA.

I personally believe the most serious problem in street lighting is the high failure rate in the first 500 hours of burning.

W. W. Brooks**: The paper is a very interesting contribution to the public knowledge regarding mercury lamp starting in low ambient temperatures. However, even though mercury lighting has been in general use for many years, industry-wide standards have not evolved for lamps operated at temperatures encountered in outdoor installations. It seems apparent that until this is accomplished the acceptance of mercury lamp lighting for such applications will be retarded.

A. E. Binder†: Concerning Mr. Freeman's discussion, a careful reading of the paper shows its basic purpose is to explain the discrepancy between the higher starting voltages measured in the laboratory by the usual methods, and the satisfactory starting obtained with lower voltages outdoors in cold climates. Two reasons were found:

First, lamps start at an appreciably lower voltage if a few minutes time is allowed at each setting, rather than to raise the voltage continuously in the customary manner. A few minutes delay at dusk in the starting of occasional lamps is relatively unimportant. Such delayed starting apparently has passed unnoticed for it has not previously been reported.

Second, the minimum temperature limits commonly specified for outdoor applications appear to be somewhat exaggerated both in value and in frequency of occurrence. Whereas lighting engineers have frequently been concerned about the coldest temperatures encountered, Weather Bureau data show that these extremes occur on only a few days a year. At dusk, when lamps are turned on, the temperature is the highest for the day. This is about 5 degrees higher than the mean temperature for the day, and considerably higher than the minimum temperature.

These two factors, plus the well-maintained line voltages of most outdoor installations account for the generally excellent field performance of mercury lamps in regard to cold weather starting.

Mr. Freeman makes three comments in regard to possible differences in starting voltage measurements. However, we find no disagreement. As to his first comment, we are aware, of course, that a lamp which is flashed on and off will require a higher voltage to start the following time. The paper states that all lamps were fully warmed up and cooled off before restarting.

As to his second comment, there is apparently little difference in the ways used to measure starting voltage by the conventional gradual increase of voltage. We took approximately 30 seconds to increase the voltage gradually in the region where starting was expected.

In regard to his third comment, design differences can affect starting. One important design variable is the ratio of arc tube diameter to arc length. The larger the ratio, the easier the starting. Both for this reason and for improved lumen maintenance, we use a relatively large diameter arc tube. A second important variable is starting-gas pressure. Small diameter arc tubes can be made to start more easily by lowering the gas pressure. But this produces more sputtering during starting, which in turn causes more blackening and poorer lumen maintenance during life.

Mr. Freeman shows a curve for 100 per cent starting of various mercury lamps, which differs from ours, where curves are given only for 95 per cent starting. Since starting voltages vary widely between individual lamps, it is impossible to specify closely from normal test quantities what voltage limit will include every lamp manufactured: *i.e.* 100 per cent. We have checked a number of competitive H400-E1 lamps from several manufacturers for starting voltages at each of our measured temperatures. Actually these measured values fell a little higher than those shown in our Fig. 1b, but the difference may not be significant. Two-thirds of these lamps measured required higher voltages to start than those given by Mr. Freeman's 100 per cent starting curve.

Mr. Till's field performance data further confirm the paper's thesis on the discrepancy between starting voltages by customary laboratory test methods and field experience.

For the H250-A5 lamp, there has been no industry agreement in the past relative to 250- or 275-volt outdoor ballasts. We feel that the data show 275 volts is more certain to give reliable starting. As yet there are relatively few outdoor installations of H250-A5 lamps, especially in the coldest areas.

In view of the fact that Mr. Till feels H400-A1 lamps have started satisfactorily outdoors using ballasts furnishing only 220 volts, as in Denver, we fail to see why more than 260 volts open circuit is necessary for an H-1 ballast, since at the coldest temperatures H400-E1 lamps start at voltages not much higher than those required for the H400-A1 lamps.

In reply to Mr. Wyatt, the ballast used furnished sine wave secondary voltage on open circuit. The voltages quoted were rms values. While peak voltage is of importance in starting, it is not the only factor. When peaked waveform is used, starting will only be accomplished if sufficient power is supplied during the peak interval. The problems of ballast design and ballast wave shape fall outside the scope of the present paper on mercury lamp starting characteristics.

In answer to Mr. Hjermstad, this paper treats only the starting voltage characteristics of mercury lamps. Operating voltages and wattages are not mentioned, since they bear no relation to starting voltage. However, all of our production lamps have always been held between 120-150 operating voltage limits.

Mr. Brooks' comments are well stated and need no elaboration.

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Comparative Analysis of "Comfort" and "Glare"

By DOMINA EBERLE SPENCER

THE PAPERS and discussions in recent issues of ILLUMINATING ENGINEERING indicate a widespread and healthy interest in high-quality lighting. It is generally realized that there is more to lighting design than merely providing high readings on a "footcandle meter"; a numerical specification of *quality* is desirable. Harrison, Guth, and Logan, in particular, have been prominent in developing numerical rating schemes. But, unfortunately, recent publications reveal a number of misconceptions that may act as barriers to future progress. The present paper points out some of these misleading ideas and suggests a criterion that is simple, yet based on a secure foundation.

The principal hypotheses that are undermining the current approaches to quality lighting are as follows:

(1) The line of sight may be considered fixed.
(2) The instantaneous state of adaptation of the eye may be neglected.
(3) "Glare" may be dissected into "discomfort," "disability," "direct," and "reflected glare"; and these fictitious subdivisions may be considered separately.

But the human eye is part of a living organism. It is not static: it is continually moving and continually adapting. Lighting should be designed to provide the best luminous environment for human beings — not to satisfy the wants of a fictitious receptor.

Let us consider these three hypotheses in order. First, take the question of the fixed line of sight. The trouble here is that actually the eyes are never fixed but are continually darting about from one part of the visual field to another. Even when we attempt most assiduously to concentrate on our work, the eyes are unconsciously exploring the entire visual field. Apparently, the relaxed eye is the eye in motion. Since such motions are natural and beneficial, the illuminating engineer would do well to recognize their existence. No system of lighting design should, therefore, be based on an elaborate analysis of the effect of a glare source at a given angle. Such an analysis may have meaning in an artificial laboratory set-up, but is meaningless in practice. *A lighting system must be designed — not for a single fixed line of sight — but for all possible lines of sight.*

The second hypothesis is that the state of adaptation of the eyes can be neglected. Actually, *the state of adaptation is the key to visual problems.* As the eye roves, the photochemical state of the rods and cones is continually changing. The instantaneous state of adaptation of the eye depends on the luminous environment and on the past history of eye motions. The response of the eye to a given stimulus depends on its state of adaptation. Though it is difficult to determine the instantaneous state of adaptation in the general case, we can easily determine upper and lower limits, fixed by the brightest and darkest surfaces in the field of view. On the other hand, if a fixed horizontal line of sight is assumed, the results predicted will be worthless, for the eye will only occasionally have the state of adaptation assumed.

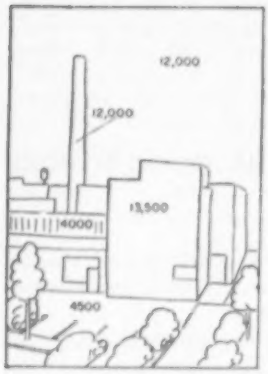
The third hypothesis — the attempt to treat various kinds of glare separately — is still with us. The engineer says, "Today I will design my luminaire for comfort." Thinking of the rigid "eye" he puts louvers on his luminaire to shield the lamps from direct view. But this does nothing for reflected glare. The eye does not respond to different kinds of glare independently, and an attempt to assume the contrary leads to inconsistencies and is a sheer waste of time.

Glare Rating

A method of assigning a "glare factor rating" to any lighting installation has been developed.[1,2,3] According to the authors,[3] the lighting system is "not likely to be criticized because of discomfort" if the glare rating is between 0 and 10. "The value of 15 is the upper limit of what is considered completely comfortable for people working in a fixed position for long periods." The method is primarily based on "experience," though some reference is made to the Holladay[4] comfort data, and a set of experimentally determined position factors[5] have subsequently been grafted[2] into the original[1] scheme.

But let us apply the method to some of the most comfortable luminous environments — to typical

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 14-17, 1953, New York, N. Y. AUTHOR: Associate Professor, University of Connecticut, Storrs, Conn.



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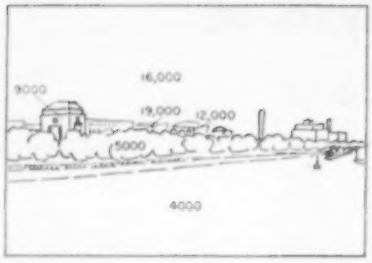

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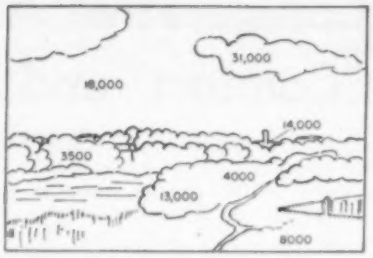
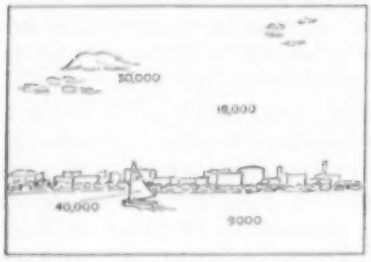


(c)

Figure 1. Some unusually comfortable fields of view and the unfavorable ratings assigned by the Harrison glare rating method.



(d)

(a) View from an M.I.T. office window. Glare factor = 847.

(b) The Charles River and M.I.T. Glare factor = 212.

(c) The Fenway. Glare factor = 800.

(d) Sailing on the Charles. Glare factor = 1431.

outdoor scenes chosen as being exceptionally comfortable. We find that the "glare factor" for unusually comfortable outdoor views varies from 200 to 1500 (See examples in Fig. 1). *All daytime fields of view are rated as intolerable* by the glare factor system. Even at twilight, the glare rating indicates abominable glare. Yet one of the authors[6] has estimated (mentally) that a clear day with the sun behind the observer should give a glare rating of about 6. In other words, he feels that such a view is entirely comfortable, yet the rating scheme gives a contrary verdict.

The illuminating engineer may argue that a glare rating system does not necessarily apply at outdoor levels, but is needed only at levels used for artificial lighting indoors. But many modern installations are using 200 lumen ft^{-2} in general lighting, and in special applications such as operating rooms values of 1000 or more are employed. So it is a mistake to develop a rating system that is limited to low values.

The glare factor system rates any lighting installation as good if the sources are small enough and are not close to the horizontal. The system completely ignores the fact that these same small sources produce intolerable glare if the line of sight is directed upward and that they produce reflected glare if one makes the mistake of looking down at his work. The glare factor system says that a method of lighting which approximates the distribution of a comfortable outdoor scene is becoming intolerable at "50 ft-c," and that bare lamps in a black room will produce a glareless luminous environment if only they are shielded by black louvers! The influence[7] of such a rating system is not beneficial to lighting progress.

The BCD Approach

In 1949, another method of studying the quality of lighting systems was developed.[8] The criterion is the "sensation at the borderline between comfort and discomfort . . . termed the BCD sensation." The work was continued by other investigators.[9,10,11] But before the illuminating engineer adopts the results as a basis for lighting design, he should ask some rather basic questions.

(1) Repeated-Flash Technique

In the first place he should think about the significance of the method by which BCD is determined. The technique of obtaining BCD data[8] is as follows. The observer adapts to a uniform field. A bright source is exposed on the first, third, and fifth seconds. Then five seconds are allowed for the subject to adjust the test source. In this time, the subject makes his declaration — "comfortable," or "uncomfortable." The cycle is then repeated with, perhaps, a slightly brighter test source.

This is presumed to reproduce the effect of looking up from the work to the luminaire. But does it? The repeated-flash technique is quite different from any experience actually encountered in practice. It might possibly have some significance in deciding how bright the flashing direction signals on automobiles should be. But how do we know whether a luminaire, which appears quite comfortable if we glance at it occasionally, would still be comfortable if it flashed on and off at one-second intervals? In fact our experience with failing fluorescent lamps indicates that there is no connection between what is measured by the BCD technique and what one might want to measure. Almost any luminaire becomes annoying if some of the lamps in it are repeatedly flashing on and off. This fact does not constitute an indictment of the luminaire.

Or to extend the technique to very large solid angles — how would one feel if the entire sky were flashing at one-second intervals? There would be strong connotations of psychological insecurity. One would probably be exceedingly uncomfortable whether the flashing sky were associated with a pleasant or an unpleasant luminous environment. Thus, *a comfort criterion based on repeated flashes can have nothing to do with practical lighting design.*

(2) Inadequate Data

The second question deals with adequacy of the experimental data. In Fig. 2 are shown all of the data on the BCD approach that have been published. The customary curves shown in papers on this subject are purposely omitted. The question is, what experimental facts do we have?

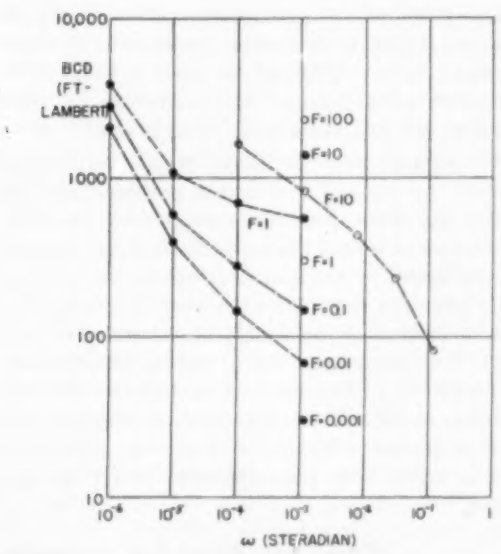


Figure 2. A summary of published experimental BCD data.

○ — Luckiesh-Guth.

● — Putnam-Faucett.

The data[11] cover the street-lighting range and have the appearance of internal consistency. But other data[8] are at variance with the preceding data[11] both in absolute magnitude and in the shape of the curves. The peculiar Luckiesh-Guth curve at $F = 10$ could not be made to fit into a family with the Putnam-Faucett curves by any correction for a possible difference in BCD criteria.

The work of Petherbridge and Hopkinson[12] is sometimes compared with the results of the BCD technique. The British research, however, seems to be confined to older lighting systems. Their experimental technique forbids the specification of the actual state of adaptation of the eyes, and no actual data are given in the paper. The procedures are considerably less definite than those used to determine BCD values, and the results are not comparable with the BCD data.

It will be noted that there are essentially *no data for the range of values used in contemporary lighting practice.* There is only one experimental point above $F = 10$, and this is for a comparatively small source subtending about the same solid angle as a half-dollar held at arm's length. The BCD data are for *street lighting systems* and for *old installations.* There are no published BCD data corresponding to modern lighting systems.

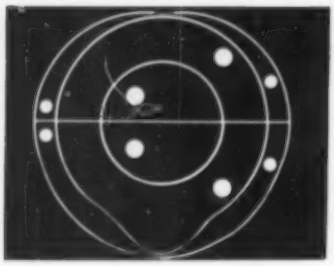
(3) The Equation

An equation[8] is given for the BCD brightness B (footlambert) of a circular source centered on the line of sight, which subtends a solid angle Q (steradian), if the flashing B is superposed on a uniform field F (footlambert):

$$B = 108\, F^{0.44}\,(Q^{-0.21} - 1.28).$$

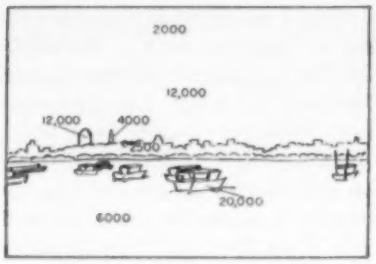
This equation does give a reasonable fit to the *seven* experimental points for which data were published. But, extrapolated to either very large or very small sources, the equation leads to erroneous conclusions. It explains that starlight is uncomfortable because the stars are too bright and that all daylight conditions are uncomfortable because the sky is too big. Need any more be said of the danger of attempting to apply such an equation to contemporary lighting design?

Another study[13] attempts to fit together all of the inconsistent comfort data by drawing a family of curves influenced by all the experiments. These curves do have the advantage that starlight is now considered permissible. And an attempt has been made to apply Logan's data for natural surrounds to give a more reasonable shape of curve at high



(a)

Figure 3. Are these two visual fields equivalent in any significant sense? Yet if the spotlights in (a), left, are properly adjusted the zonal fluxes can be made equal to those found in (b) right.



(b)

values. But the curves are still strongly influenced by the BCD points at $F = 10$. It is probable that a radical change in criterion occurs between the parts of the curves drawn in the region of the BCD data and in the outer region where data from non-flashing natural surrounds have been used. Although the Logan and Lange curves may be considered as an improvement over the BCD equation, the data on which they are based are so inadequate that *they cannot be considered a reliable basis for further work.*

Consequently, there is no need to criticize other phases of the application of the BCD technique such as the fixed horizontal line of sight, the ambiguity which appears when the visual field contains more than one glare source, or the effect of the immediate background. As there is no adequate experimental basis for the BCD equation, and as the significance of such data for lighting design is highly questionable, we can conclude that there is no significant numerical method of assessing the "comfort" of a luminous environment.

The Zonal Flux Method

In a series of interesting papers, Logan[14, 15, 16, 17] has studied the distribution of light in natural surrounds associated with the 70°F annual isotherm. He assumed that man evolved in a luminous environment which is not essentially different from ours (at the 70° isotherm) and which therefore provides comfortable conditions. These conditions were measured, for example, in central New York State during the summer. The attempt was then made to design interior lighting so that the measured outdoor variation was reproduced.

The principal trouble with the system is that the characteristic of the luminous environment measured by Logan is a characteristic that has *no* visual significance. The luminous flux reaching the eye is evaluated in eight arbitrarily defined zones. The difficulty is that the eye cannot see zonal flux and that no known visual characteristics are correlated with this measurement. According to the analysis, a uniform field filling one of the zones, and a dark field containing a single glare source are considered equivalent if both deliver the same number of lumens. (See Fig. 3.) Therefore, if we have eight spotlights in a black room, put one in each of the zones, point them at the observer and adjust them until the zonal fluxes are within the prescribed limits, we have a luminous environment that is supposed to be the equivalent of a comfortable outdoor scene. None of us would consider such a battery of spotlights as being the visual equivalent of a landscape.

Another difficulty of the zonal flux method is the assumption of a horizontal line of sight. If a glare source is just out of the field of view, it is considered to have no effect. Yet a slight motion of the ever-roving eyes will bring this glare source into the field of view.

A third disadvantage of the zonal flux analysis scheme is its complete neglect of the state of adaptation of the eye. Comparatively uniform fields of view are desirable at daytime outdoor levels; but certainly, if the quantity of light is sufficiently decreased, much greater non-uniformity is permissible. On this question, nothing is said.

To conclude the discussion of the zonal flux method, we can say that it has the advantage of saying that *many good luminous environments are good.* The favorable daylight distributions treated as intolerable by the glare rating system and the BCD approach, here form the basis of the system. Yet by presenting the analysis in terms which are not visually significant, many glaring distributions are approved. Thus the flux analysis scheme lets both the sheep and the wolves enter the fold. We need a system which is more closely related to human vision than any discussed so far in this paper.

What To Do About Eye Movements

As pointed out at the beginning of this paper, the human eye is continually in motion. Although techniques exist for making accurate measurements

of eye motions,[18] the illuminating engineer does not ordinarily need to resort to such complexity. He can rather study the enclosure for which he is attempting to design the lighting and present a summary of:

(1) The *most important lines of sight* (those essential to performing the task if work is to be done),
(2) Lines of sight for view of the brightest part of the luminous environment,
(3) Lines of sight for view of darkest part of luminous environment.

Example — Classroom Lighting

Essential lines of sight for students are

(1) Eyes directed downward to desk for taking notes and reading, and eyes directed toward all parts of the chalkboard.
(2) Direct view of luminaires and windows.
(3) View of floor.

Or if there is to be varied activity in the room, as in many elementary schools, all possible lines of sight should be considered. The lines of sight which will be employed most often can be considered to be more important than those which will be used only occasionally.

State of Adaptation

The response of a rod or cone in the retina depends on the instantaneous chemical state of the substances which participate in the photochemical reaction. It is found that the state of adaptation of the fovea (a measure of the integrated response of the 10^5 cones which make up the fovea) can be specified by a single number called the "adaptation helios."[19] To specify the minimum perceptible contrast or the minimum perceptible visual angle,[20] at a given instant, we must specify the adaptation helios. Specification of the adaptation thus enables us to make certain definite statements about the state of the eye.

The calculation of "adaptation helios" has often been said to be a difficult procedure. In reality, the procedure is exceedingly simple in most practical cases. If the field of view is reasonably uniform (no very bright glare sources in the field of view), the adaptation helios can be taken as the average helios imaged on the fovea (a region subtending about the same solid angle as a dime held at arm's length). If one looks for a minute or two at a bright luminaire against a dark background, the adaptation helios is still the helios of the luminaire (within less than 10 per cent) provided the luminaire is large enough to fill the fovea. For complex cases in which a number of sources are present, the exact adaptation helios for a given line of sight can be determined either by measurement with a photoelectric meter as was described by Hurd[21] or by employing the general formula developed by Moon and Spencer.[22]

Perhaps it should again be stated that the practicing illuminating engineer can analyze existing lighting systems with only two pieces of equipment: a helios meter and a dime. Or, if he wants to work with lighting systems not yet built, he need only spend five minutes with the interflection tables. By these simple procedures he can specify the range of adaptation as accurately as is necessary in 99 per cent of lighting practice.

Adaptation Ratios

The next question is what adaptation ratios should one try to obtain in a luminous environment? A criterion of 3:1 was recommended by the first Committee[23] on Standards of Quality and Quantity of Interior Illumination. A number of reasons were behind the choice of this particular value.

It was based, in part, on the ability to see detail. If the state of adaptation is suddenly changed by a factor of 3, either increased or decreased, a number of visual researches indicate that the threshold for typical visual tasks will change by a factor of 3. As we are generally working under suprathreshold conditions such a small variation in the threshold will not ordinarily be noticed. The 3:1 ratio,[24] in the view of the author, meant a 3:1 *adaptation helios ratio.* If it is satisfied, then visual thresholds do not change radically no matter how the eyes wander about the visual field. For example, if a luminous ceiling is three times as bright as the work and the floor one-third as bright the 3:1 adaptation ratio is satisfied.

Suppose that a person is adapted to the work and is just able to see a detail of size δ. He then stares at the luminous ceiling or at the floor until he becomes adapted to it. His threshold is then 3δ when he looks back to his work. Ordinarily one does not look at the ceiling or floor long enough to become entirely readapted, so the state of adaptation is disturbed by a much smaller factor than three.

According to other members of the Q and Q Committee, the 3:1 ratio had different connotations. Our chairman, Dr. Matthew Luckiesh, felt satisfied with the same ratio because it was in accordance with his blink tests and other psychological investigations. These all tended to show that a 3:1 ratio produced no appreciable disturbance; but if this ratio was greatly exceeded, the deleterious effects of a non-uniform surround appeared. Mr. George Ainsworth approved of the same ratio because it was characteristic of the dis-

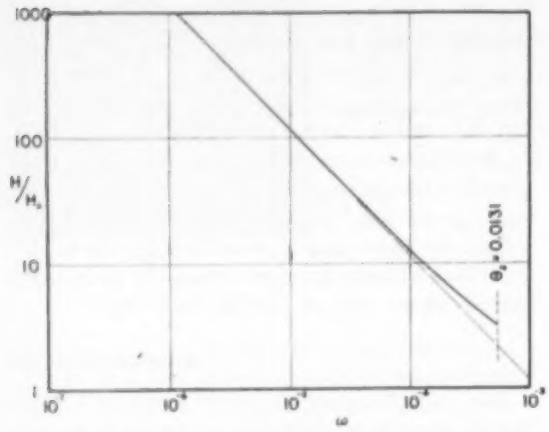


Figure 4. Allowable ratio for glare source subtending a solid angle of ω steradians (for 3:1 adaptation criterion).

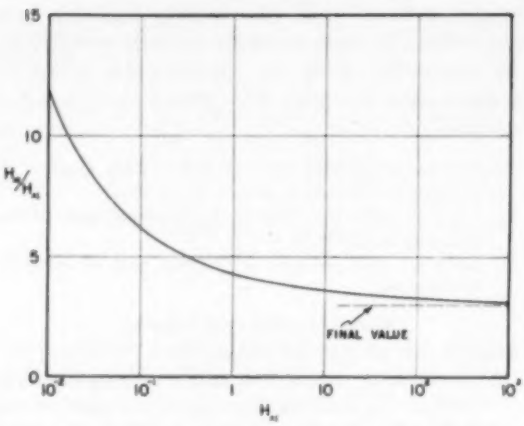


Figure 5. Allowable adaptation ratio as a function of state of adaptation of eye. From the levels now used in interiors up to daylight levels the ratio remains essentially constant.

tribution of light in his favorite "lighting laboratory" (a green field, 20 minutes before sunset, when the quantity of light is of the same order of magnitude as that used in interior lighting). The Committee also studied Mr. Henry Logan's researches on favorable flux distributions in nature and found that the adaptation ratios here were also about 3:1.

As the ratio was based on so many different viewpoints, it was decided to present it as a simple ratio with little explanation of its meaning or significance.

Some comments are also in order on the implications of an adaptation ratio criterion. The first question is whether a 3:1 ratio requires a monotonous surround. Actually considerable variation is possible.[20] If the source is very small, it can be very bright, as shown in Fig. 4. Yet for sources large enough to fill the fovea (dime held at arm's length), the simple 3:1 ratio is *the desired criterion*. Another question that often occurs is whether the 3:1 adaptation ratio should be used at all levels. As shown in Fig. 5, the adaptation helios ratio can be greatly in excess[20] of 3:1 without producing undesirable visual effects at very low levels of adaptation.

Consequently, for glare sources large enough to fill the fovea and for large amounts of light, the simple 3:1 ratio has a valid basis in terms of ability to see small detail. For very small sources, or for very small amounts of light, ratios greater than 3:1 may be used safely, as shown in Figs. 4 and 5.

The paper has attempted to explain how three proposed methods of dealing with quality in lighting are erroneous. The simplest and most reliable criterion is still the 3:1 ratio, which directs us toward the most comfortable conditions found in nature.

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DISCUSSION

WARD HARRISON*: There is just one half hour on the morning program of the Conference for presentation of this paper, including discussion. Twenty minutes is allotted for the paper itself, leaving not more than 3⅓ minutes apiece for discussion by each of the three groups whose views and investigations the author seeks to demolish. This is an excellent illustration of the point I tried to make previously, namely that there are too many papers on the program at each session. The British, by giving half a day to each subject, insure that there is time for all of those interested to express their views.

Dr. Spencer has made a number of categorical statements. I regret that I have time and space to reply only in a similar vein and that my comments may seem blunt-spoken and but illy express the cordial feeling which I hold toward the author.

1. Mr. Meaker and I do not consider that one's line of sight is fixed. As our premise we have repeatedly described the eyes as "drifting over a variety of easy visual tasks."

2. We know that human anatomy is such that it is not particularly convenient or comfortable to direct one's eyes much more than 10° above the horizontal unless one first leans his head back and usually his feet up on a chair or a desk. The refinements of lighting are not intended primarily for this group.

3. Glare factor evaluations do not ignore the adaptation of the eye.

4. Direct glare and reflected glare are separate phenomena and must be evaluated separately.

5. Glare factors of 500 or more are not abominable or intolerable, in fact most chain stores lighted with enclosed globes or bare fluorescent lamps have glare factors as high or higher than 500. The lighting chosen for these stores would not be found satisfactory for office or drafting room use in which we favor a figure of 15 or less.

6. Glare factors are admittedly empirical; they were planned to apply to interior lighting up to let us say 100 footcandles, which represents at least 99 per cent of the installations. They were not intended to cover all outdoors; to attempt to do so would involve making the formula much more complicated. However, they do not fit outdoors so badly as the author would imply. Glare factors of 500 or more, as found in chain stores, are not uncommon out-of-doors on an overcast day which, contrary to some opinion, does not represent a particularly comfortable visual environment. As Dr. Weston has emphasized there is a tendency to confuse an interesting and pleasurable scene with a comfortable one. As you well know, looking out of a window (Fig. 1a) is very different from facing that window all day. In many cases you will find that an outdoor scene becomes appreciably more comfortable although not more interesting if you shade your eyes with your hand. That is a good test for any lighting system.

7. Some sunlit scenes, especially where there are trees for a background, have very reasonable glare factors.

8. Bare lamps concealed by louvers, in a black room may be quite comfortable, although not an inspiring method of lighting for one who is required to sew on dark goods or view a grey wall chart.

9. It is eight years since the first presentation on glare factors. We have not yet learned of any case where glare factors have led people astray; we have not yet been shown a comfortable lighting system for office, school or drafting room use where the glare factor is much above 15. Conversely we have not learned of a room which was uncomfortable from the standpoint of direct glare which had a low glare factor. Finally we have not yet found two installations, one substantially more comfortable than the other from the direct glare standpoint, where the glare factors indicated the reverse.

10. Reflected glare is another subject but an important one. Uniformly illuminated or luminous ceilings are not a panacea for reflected glare as the photograph (Fig. D-1) demonstrates. Both views are taken at the doorway of an indirectly lighted room. The magazine lies flat on a small table placed in the doorway. In the view at left the camera is outside the room, pointed at the magazine. Contrast the reflected glare in this instance with the second result when

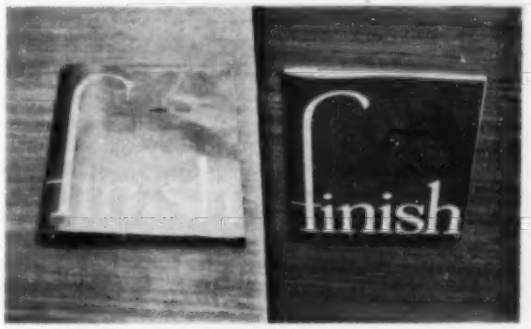

Figure D-1.

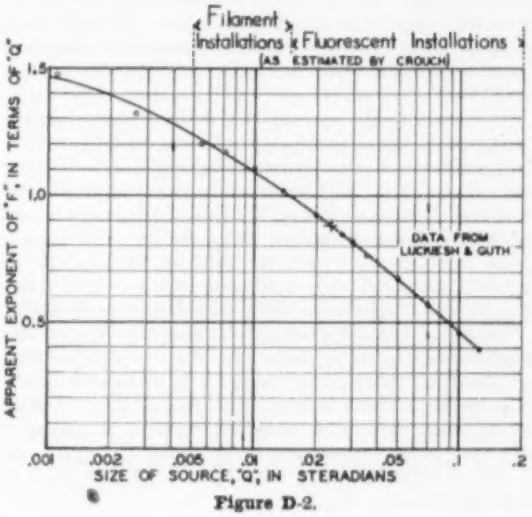

Figure D-2.

*Consulting Engineer, Cleveland, Ohio.

the camera is in the room pointed out and there is no chance for reflected glare.

11. Any system such as the 3:1 ratio which ignores source area is unsound. The line drawing shows that, for most fluorescent installations, surround is of lesser importance that source area for it will be noted in fluorescent section the exponent curve is mostly below the 1.0 line. This indicates that indirect lighting or luminous ceiling installations are not *per se* entirely comfortable in all cases. In very large areas with high footcandles they may be the reverse.

H. L. LOGAN[*]: As long as methods for attaining "quality" in lighting are in the theoretical stage critical discussions (such as this paper of Dr. Spencer's) are needed; but it is important in such discussions to distinguish between real issues that need to be resolved by further work and study, and artificial issues that serve only to confuse and obstruct general understanding.

Dr. Spencer's discussion contains both. First let us look at her three "hypotheses" that "are undermining the current approaches to quality of lighting." The first is: "*The line of sight may be considered fixed.*" This is a mistaken interpretation of conventional procedure. Conventional procedure is to inspect a field of view (either on paper or *in situ*) and to select a particular line of sight out of the many possible lines of sight, for exploratory analysis. This line of sight may or may not be horizontal. Any line of sight may be used, but it is common sense to pick the line that offers the safest approximations. As human beings are bipeds and face a field of view from a vertical position in the situations with which lighting engineers are mostly concerned, the horizontal line of sight usually offers the best approximation. Different or additional lines of sight are used when individual circumstances dictate their need. The writer used both upward and downward inclined lines of sight in his paper, "The Mechanics of Designing Optimum Lighting Patterns." This conventional procedure of *selecting* an appropriate line of sight is quite different to considering the line of sight "fixed."

So much for the artificial issue. The real issue behind Dr. Spencer's mis-identifying a *selected* line of sight with a *fixed* line of sight is that it is possibly "an over-simplification to speak of the adaptation level in an interior," which is the assumption made when one line of sight is used for evaluation purposes. The question is, does the retina stabilize at some particular level or around some particular level in an artificial interior, where all the brightnesses are steady and fixed instead of fluctuating as they do in natural lighting conditions?

It is undoubtedly true that the level of adaptation will change with change in direction of view, if the new direction encounters a *sufficiently* different brightness and fixates that brightness for the time necessary to permit the adaptation change to occur; but is this statistically characteristic of interior seeing conditions? When the eye wanders, does it, in representative present day interiors, normally encounter *sufficiently* different brightnesses and does it normally wander with the degree of attention necessary to fixate?

The experience of the writer leads him to answer the last two questions in the negative; but there is need for work on adaptation in practical situations to ascertain definitely what happens, and how approximations can best be made. In any event some simplification will always be necessary, and the author believes with Dr. Harrison and others that the adoption of a principal line of sight for evaluation purposes (often horizontal) is a reasonable simplification in our present state of knowledge.

Dr. Spencer's second "hypothesis," namely that lighting engineers consider that the "instantaneous state of adaptation of the eye may be neglected" is partly answered by the previous discussion. Dr. Spencer is really referring to the mathematical abstraction involved in interrupting a function curve at any particular point. The value at the point of interruption is considered by mathematicians to be the "instantaneous value," but it represents an abstraction that may have no counterpart in reality. It is certainly possible to put down a series of adaptation level values on a piece of paper and draw a continuous line through them, any point on which may be considered to be an instantaneous value, but to assume that that is comparable to the way in which the eye operates is to make an extremely doubtful assumption.

Physiological reactions of man to environmental stimuli are range rather than pin-point reactions. The body receives stimuli in continuous fashion; but the body acts as if it was full of thresholds, so-to-speak, and a stimulus must exceed a certain amount and last for a certain time, before the body moves from an existing threshold to a new one. In short, although light enters the eyes in a continuous flow, the adaptation process excited by this light, if it parallels comparable physiological responses, moves from threshold to threshold rather than in the continuous smooth manner required to justify the concept of "instantaneous adaptation."

In short, the idea of a rapidly varying state of adaptation of the eye in a static, artificial environment is not supported by any facts in possession of the writer. As stated previously, "there is need for work on adaptation in practical situations to ascertain definitely what happens."

Dr. Spencer's third "hypothesis" to which she objects is "Glare may be dissected into 'discomfort,' 'disability,' 'direct' and 'reflected glare'; and these fictitious divisions may be considered separately." One of the fundamental abilities of Man that sets him apart from all other creatures is his ability to abstract a facet of the truth and consider it apart from other facets. There is nothing improper nor unscientific in abstracting from the phenomena of glare certain aspects, such as its effect on conscious feeling (discomfort), its effect on visibility (disability), or certain aspects of manner of encounter, such as primary glare (direct) or secondary glare (reflected).

Glare itself is an abstraction from light; and if it is invalid to abstract the various aspects of glare, it is equally invalid to abstract the various aspects of light. Footcandles, footlamberts, lumens, candlepower, the notion of brightness, are all abstractions we make for convenience and clarity from the reality of visible radiation.

If abstractions of glare are "fictitious subdivisions" then Dr. Spencer must be prepared to label brightness and brightness ratios "fictitious subdivisions," as they are abstractions of the same type as those she objects to, having no existence outside the mind of man. In that case her thesis evaporates.

Dr. Spencer raises another artificial issue when she says, "according to the (flux) analysis (method), a uniform field filling one of the zones and a dark field containing a single glare source are considered equivalent if both deliver the same lumens." Dr. Spencer then continues with her example of eight spotlights in a black room aimed at the observer.

Her example has no bearing on the matter and is invalid. The writer has pointed out time and time again that the

[*]Holophane Co., Inc., New York, N. Y.

particular natural fields investigated met certain criteria that established them as models. In all cases all the visual zones were filled with flux and none of the models bore any resemblance to Dr. Spencer's fancy. It would be unscientific and a complete disregard of the facts to try to evaluate a field of view lighted by eight spotlights aimed at the observer on the basis of a comparison with the natural models. They would not, as Dr. Spencer admits, be "equivalent," as they would have no features in common.

Artificial fields of view should be evaluated on the basis of the natural models only when they conform to the main features of the natural models; namely that light proceeds from the entire field to the observer, and the glare sources amount to at least one percent of the field of view in size. The spotlight arrangement of Dr. Spencer could not be validly evaluated by the flux method for both reasons. First, light would not be coming from the whole field as in nature, but only from the spotlights; and second, eight conventional spots in an average interior would amount to less than one-tenth of one per cent of the field of view.

The lower limit of one per cent of the field of view for the glare sources (usually the artificial lighting units) derives from the fact that the smallest "glare" source encountered in the natural models was that size. As bare lamp systems (incandescent) usually run less than one per cent of the field in the size they should not be evaluated by the flux method. They are too dissimilar from the natural models. The same applies to any lighting system that runs less than one per cent of the field in size, which includes some conventional incandescent systems and some bare tube fluorescent installations. With such systems we have to resort at present to one of the various "comfort" yard-sticks to secure an estimate of what may be expected from the installation.

The author is unable to understand Dr. Spencer's reasoning in the statement that "The principal trouble with the (flux analysis) system is that the characteristic of the luminous environment measured by Logan is a characteristic that has no visual significance." The author is amazed to learn, after thirty-four years in the lighting field, that light has no visual significance, as that is what he measured. The writer made approximately 7000 measurements of the way in which light was distributed in the model natural fields of view; but instead of expressing these measurements in footlamberts, he expressed them as variations from a uniform field of view, thinking that the range of departure from a uniform field that was found in the natural model fields would be a safe guide to follow in designing artificial fields.

It is quite true that he measured the flux in zones, which had the effect of immersing localized brightnesses in a generalized pattern of flux distribution; but as long as the brightness variations within a zone are not sufficient to change the character of the pattern nor the total light from the zone, an artificial field of view can be compared with the natural field and worthwhile conclusions drawn from the comparison.

The writer has not yet seen any scientific data indicating this view to be incorrect, and is greatly intrigued by a statement in a report of the National Illumination Committee of Great Britain on "The Design of the Visual Field" referring to Dr. Spencer's work, as follows: "The figures of brightness obtained from (Spencer's) interreflection tables — give no indication of localized brightnesses, but only the average brightness of large areas, *i.e., their total flux emission*. The data cannot be interpreted as a brightness pattern but *only as a generalized pattern of flux distribution* (which could, in fact, arise from a great variety of brightness patterns)."

In other words, Dr. Spencer's outstanding contribution to illuminating engineering — the interreflection tables — determine the same "characteristic of the luminous environment (as) measured by Logan" and which, in Dr. Spencer's words, "is a characteristic of no visual significance."

With respect to Dr. Spencer's 3 to 1 technique and the simple equipment needed by a lighting engineer, the reader is referred to the previously mentioned report of the National Illumination Committee (Great Britain) on "The Design of the Visual Field" (*Trans. I.E.S.*, London, Vol. 18, No. 8, 1953). This report gives a broad idea of the great range of factors involved in satisfactory lighting design. It cannot be reconciled with the over-simplification proposed by Dr. Spencer. If a meter and a dime is all that is needed by lighting engineers, where is the need for *them!*

R. L. Oetting*: Finding out how to evaluate the comfort of lighting systems is one of our most pressing needs and it is time we got on with it. Dr. Spencer's paper helps in two ways. It presents a simple exposition of the basis for the brightness ratio criterion and it summarizes Dr. Spencer's opinions of the various comfort appraisal systems which are under consideration by the Committee on Standards of Quality and Quantity. The paper and the discussions should bring out in clear perspective the divergent principles and approaches which are involved in these proposals. It is hoped that the comments will be constructive rather than acrimonious so that we may calmly and objectively accomplish the job before us.

My coments consider differences in addition to those described by Dr. Spencer and inquire into the validity of certain interpretations which differ from hers.

Should our recommendations anticipate *all* contingencies or most of them? "All," says Dr. Spencer, as she endorses the principle of perfection: "*A light system must be designed — not for a fixed line of sight — but for all possible lines of sight.*" The statement is more appropriate in the thinking of many engineers when "probable" is substituted for "possible" with regard to lines of sight. Until we adopt one proposition or the other, we will have the confusion of differing conclusions.

What about a fixed line of sight; has any system assumed such a condition? By interpretation, it can be implied in even the brightness ratio criterion. In this instance, the eyes are assumed to "look at" individual elements all about the environment. As they pause to do so, the line of sight is rigidly fixed to gain a sharp foveal impression. It becomes a rather apparent exaggeration to contend that this system thereby assumes a fixed line of sight. In a similar way, the contention that systems employing a *reference* appraisal direction assume a fixed line of sight is also unwarranted. None of them do.

Does the brightness ratio concept differ from other systems in basic concept? As Dr. Spencer's explanation in this paper brings out so clearly, the basis of the criterion is the effect a *change* in brightness has upon our *ability to see detail*. Other considerations are mentioned in support of the 3:1 ratio but a shift in visual *thresholds* is the reference factor of this approach. This factor may be related to visual comfort; but has the correlation been shown? Its use as a criterion of comfort raises the question of whether whether this system recognizes visual comfort as a distinct, directly discernible sensation. If not, we can expect the

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conclusions derived from this criterion to be markedly different than those from systems predicated on the existence of such a sensation.

What of practical experience? To paraphrase a statement by Dr. Spencer, it has been found that *many good luminous environments meet the brightness ratio criterion.* But many other good environments do not. This has been a more serious situation than that in which some environments meeting the criterion have not been completely satisfactory. Such experiences raise doubts as to the propriety of the 3:1, a 9:1 or any other single-ratio criterion. By contrast, glare factors — which are not solely a criterion of perfection — have been fulfilling their purpose of guiding lighting designs toward desirable levels of direct-view comfort. Regardless of whatever complexity there may be in the preparation of glare factor data, the results are easily used. There are thousands of tables in the hands of engineers, architects and consumers. These data are helping to raise the quality of installations in offices, schools, factories, libraries and other areas in which visual comfort is important without restricting the choice to indirect or luminous ceiling types. Incidentally, reference to any of these tables will show that 50-footcandle installations with these systems are *not* rated as approaching the intolerable. On the contrary, they indicate high orders of comfort and acceptability.

Finally, we ask: Are the conditions and situations of direct and reflected glare identical? We think not. The eyes are common to both but the surfaces in which reflected glare may become a specific problem are not involved in the same degree in direct glare considerations. The elements of a lighting system which are of greatest direct-view importance often are of little or no consequence as far as reflected glare is concerned. We will have a higher order of satisfaction with all types of lighting if we can obtain improved surfaces and finishes. We need to emphasize their importance, not deepen the present complacency by an oversimplification of the problem.

DOMINA EBERLE SPENCER*: Perhaps the chief value of a paper of the type I have presented lies in the resulting discussion. There are two features common to all three comments:

(a) A refreshing denial of complete addiction to the fixed line of sight,

(b) A general admission that the state of adaptation should be considered.

None of the discussion changes the conclusions of the paper. I would like to thank Dr. Harrison, Mr. Logan and Mr. Oetting for their interesting comments and will now attempt to reply to each in turn.

Dr. Harrison has confronted me with a set of eleven categorical statements each of which deserves comment.

(1) Although Dr. Harrison and Mr. Meaker do not say that all human beings at all times stand in the doorway with eyes fixed on the center of the opposite wall, their formula strongly implies this assumption. The glare-factor formula *could* be applied to other lines of sight but I have not seen this done. Different results would certainly be obtained if the "line of sight" of the formula were directed up or down. It is the failure to consider more than one line of sight which is one of the most serious faults of the system. The published glare factor ratings of lighting systems, if they mean anything, have to do with the horizontal line of sight assumed in calculating them. Thus, whether by edict, intention, or custom, the net result of the current practice is to associate a fixed line of sight with the glare-rating system.

(2) As I write these comments I sit on my sofa. My feet are also on my sofa and my line of sight is about 60 degrees below the horizontal. When I was a student, I generally chose a seat in the front row. If I looked at the chalkboard my line of sight was often 30 degrees above the horizontal. According to Dr. Harrison the "refinements of lighting" are not for me, yet I seem somehow to have become involved in the subject! Even though I look up and down and sit in positions not approved by Dr. Harrison, I like to be able to see what I am doing. And I suspect there are many other people who would also like to see well in more than one position. It is for such people that I design lighting — not for people confined to a nearly horizontal line of sight by a visible or invisible straightjacket.

(3) Although the glare-factor formula includes the so-called "field brightness" it does *not* include a physiologically significant specification of the state of adaptation of the eye.

(4) When we experience "glare" we do not distinguish between headaches associated with direct and reflected glare. One head experiences both. Only the line of sight is different. Any basic method of analysis should apply to all lines of sight and thus include both direct and reflected glare.

(5) Does Dr. Harrison consider the bare-lamp systems of the super market more satisfactory than the particularly comfortable outdoor scenes for which I found, in most cases, still higher glare factors? Or does he say that, if a glare factor of 1431 is associated with sailing on the Charles, then glare factors of 1431 are not meant to be unsatisfactory? If they are not, why calculate glare factors at all?

(6) It is somewhat difficult for me to understand exactly what Dr. Harrison means by "comfort." Whatever the system of analysis the *same* system should apply to all luminous environments whether natural or artificial.

(7) In my examples of Fig. 1 (b) and (c) the scene is sunlit, there are trees for background, yet the glare factors are 212 and 800!

(8) It seems hardly necessary to defend such a terrible system of lighting as bare lamps with black louvers in a black room. No illuminating engineer in his senses would recommend such lighting for close visual work. Even the tailor sewing on black cloth will be annoyed by reflected glare from needle and scissors.

(9) In my experience I have encountered many people who have been led astray by the glare-rating system. The tendency is to approve luminaires which are serious offenders with respect to reflected glare and to disapprove systems which approximate the best distributions found in nature.

(10) I have never said that it is impossible to find appreciable reflected glare in all orientations under all luminous ceilings. If the 3:1 adaptation helios criterion is satisfied (sufficiently high reflectances are used) there will be no appreciable reduction of contrast when reading printed matter, and reflections from glossy surfaces will not be bright enough to cause serious modification of the state of adaptation. Even glossy photographs can be viewed satisfactorily if the amount of diffuse light incident on the surface is sufficiently large in comparison to the helios of the source. If Dr. Harrison would close the door behind him (if it is not a black door) or move to the middle of the room before taking his photographs he would find them much less dramatic.

(11) As indicated in Fig. 4, the 3:1 adaptation helios criterion does not ignore the solid angle subtended by the source. No one has said that luminous ceilings are *per se*

*Author.

comfortable in all cases. What I have said is that *properly designed* luminous ceilings are exceedingly satisfactory to live and work under up to and including the levels obtained in natural lighting on an overcast day.

Mr. Logan protests that he has not considered the line of sight to be fixed. He has merely *selected* a horizontal line of sight as appropriate to bipeds. Mr. Logan nearly always behaves as though the line of sight were horizontal and if he does employ other lines of sight he is careful not to look up at the luminaires or down at their reflections. As Mr. Logan correctly states, the question is whether the state of adaptation is essentially constant in an artificial environment.

The state of adaptation depends on the instantaneous helios distribution in the field of view and also on the distributions viewed in the recent past. With normal eye movements, the state of adaptation is continually varying. The same visual result is obtained whether the helios distribution is changing or the eyes are moving, whether the surround is natural or artificial. This concept is basic to the interpretation of all transient visual phenomena and is amply supported by experimental data on dark adaptation and on light adaptation. Though the phenomena may be described in terms of quanta of light, except for the completely dark adapted eye, the number of quanta involved are so large that for all practical purposes the process may be considered to be continuous.

On the discussion of the ability of the human being to make abstractions, it should be noted that an abstraction may be *useful* or *useless*. The concept of helios is a *useful* abstraction. The notion of reflected glare is not to be condemned because it is an abstraction, but because it is a *useless* abstraction.

In my example of Fig. 3, I would be quite willing to replace the eight spotlights by four lens plates or troffers and their reflections in a glass desk top. It is not essential whether they cover 1 per cent or 10 per cent of the field of view. If their helios is properly adjusted, the flux analysis criterion can still be satisfied without producing good lighting.

If Mr. Logan is consistent in his limitation of the application of his scheme only to "artificial fields of view" which "conform to the main features of the natural models" he will have a system which is strikingly similar to the 3:1 adaptation helios criterion. Spotlights will be forbidden. The helios of large area sources will be limited to an overall range of about 10:1 between the brightest and darkest areas.

In the discussion of flux and helios, both Mr. Logan and the British are somewhat careless as to nomenclature. They have the tendency to equate two quantities if one can be calculated from the other. Zonal flux can be calculated from the helios distribution but the converse is not possible. The interflection tables give the helios of walls, ceiling, and floor for lighting systems in which the helios of ceiling and floor are essentially uniform. When they are applied to rooms containing bright luminaires, the helios of the luminaires themselves must, of course, be treated separately.

Mr. Logan wonders if lighting engineers would still be needed if the simple 3:1 adaptation helios criterion were widely used. The *intelligent* use of a helios meter and a dime or of the interflection tables still requires considerably more talent than most illuminating engineers have made use of in the past.

Mr. Oetting claims he deals with *probable* lines of sight rather than *possible* lines of sight. Is it not both *probable* and *possible* that a General Electric employee occasionally looks down at his work, and also that he steals a glance at a maddening luminaire?

The system presented in this paper makes no pretense of defining or assessing "comfort." What it does is to tell whether we can see well when we perform *visual tasks* in a luminous environment. If we want to go to sleep, we may be more comfortable with the lights turned out!

Practical experience has shown that the glare-factor system approves many poor lighting systems. It leads to the choice of luminaires which are attractive when inspected casually from the door but are unsatisfactory if one looks up or down. It also tends to put any system which approaches good outdoor conditions under unjustified suspicion.

It is, of course, true that reflected glare would cease to exist if all surfaces were perfectly diffusing. However, I suspect that lead pencils, glossy ink and the printed page are here to stay for quite a few years. As long as ILLUMINATING ENGINEERING is a potential source of reflected glare, the illuminating engineer should design lighting under which one can read it without annoyance.

New I.E.S. Residence Lighting Practice Now Available

The new I.E.S. Recommended Practice for Residence Lighting, complete with appendices and subject index, has now been published in 44-page booklet form. The new practice is based upon earlier I.E.S. recommended practices, as well as upon the 1950 "Contemporary Lighting in Modern and Traditional Interiors" and the 1951 report "The Functional Visual Activities in the Home and the Location and Extent of the Associated Areas to be Illuminated." However, the new Recommended Practice represents an enlarged treatment of the subject and is specifically directed not only to Society members but also to residence architects, interior decorators and designers, lighting equipment designers, and educators.

Color Chart. — One feature of the new Recommended Practice for Residence Lighting is the color-chip chart which shows a suggested range of colors and their reflectances, for ceilings, walls and floors. For use with this chart, a full page of the report deals with the lighting environment to be created with colors and the effects of light upon them.

The I.E.S. Recommended Practice for Residence Lighting is primarily devoted to the basic lighting requirements for family activities. It is completely illustrated and much of the regularly-used information is in table form.

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Multichromatic Colorimeters

By JOZEF COHEN

Workers in colorimetry are familiar with three general types of instruments—colorimeters, spectrophotometers, and automatic computers for the tristimulus values. This paper will describe the theory and development of an instrument of the first type, and will indicate the manner in which the theory may be extended to the others.

COLORIMETERS are classified as monochromators, as developed by Kirschmann[22] and Parinaud;[33] trichromatic colorimeters, as developed by Allen,[3] Cohen,[5] Donaldson,[7] Guild,[13] Ives,[17] Manley,[25] Newhall,[28] Verbeek,[36] Wright,[39] and Zirnike;[42] or monochromatic-plus-white colorimeters, as those produced by Nutting[32] and Priest.[34] Sources used with colored papers[6] or standard filters[12] are also a form of colorimeter, and many of them together constitute a "subtractive" colorimeter as that of Jones.[19]

Each of these instruments is restricted in the type of spectroradiometric functions which it can produce, and their use in psychophysical experiments is correspondingly limited. The present paper will describe an apparatus which will produce any predetermined spectroradiometric function, and thus generalize all of the above colorimeters. The radiations shall be real mixtures in space and not simulated mixtures in time as the colorimeters of Maxwell,[26] Nickerson,[29] and Young.[41]

The Instrument

The scientific description of the color sense is the most elegant of all psychophysical phenomena. This is true because concise mathematical theory describes a simple model which bears an isomorphic relationship with each color sensation. It is also true that the development of this model is dependent upon what may be called "the identity principle in space."

It has become the practice in investigations of the color sense to allow the observer to view two fields, by tradition two semi-circles to form a bi-partite field; variations are given by Gibson.[10] The observer is requested to state when they look alike, or what is the same thing, makes them look alike with an adjustment. The observer need not, and does not, report the nature of the sensation. The spectroradiometric distributions of each field, though different, evoke the same sensation. The identity principle is effective with the human eye only when the two fields appear side by side in space; it is ineffective when the fields are displaced in time, as memory for color is poor. That the identity principle in space is possible is fundamentally responsible for the excellence of observed data concerning color vision as compared to other psychophysical investigations.

It is our problem, then, to construct an apparatus to present to an observer the view shown in Fig. 1. Here is a bi-partite field on either side of which we wish to produce any random spectroradiometric distribution. We also wish to control the surround of the bi-partite field, since it is known that the nature of the surround will affect the equivalence of sensation of the two sides. The bi-partite field wants to be large. Although most psychophysical investigations will require only a 2-degree field because of the macular pigment, as indicated by Judd and Plaza,[20] some will require a larger field; the field can always be made smaller. When the construction of the multichromatic colorimeters is

Figure 1. The bi-partite field as it must theoretically be seen by the observer. The field should be large, and the surround controlled.

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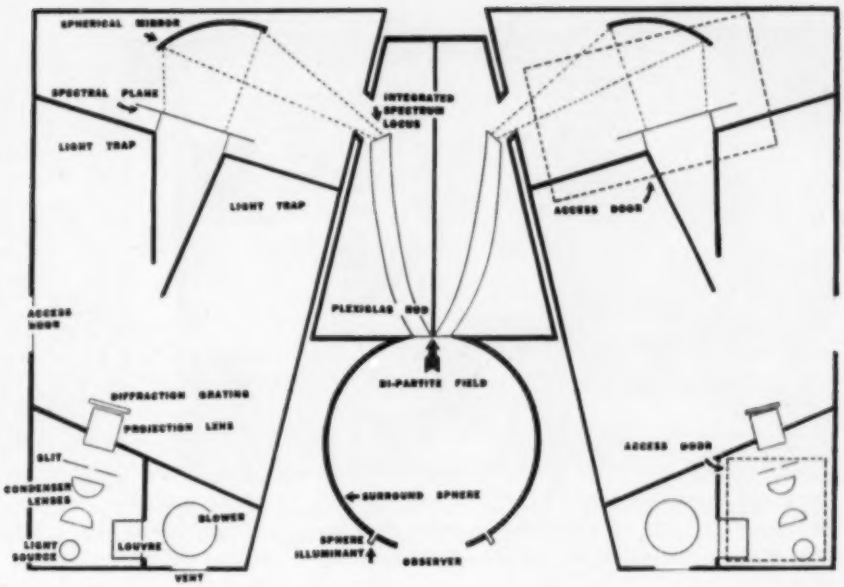

Figure 2. Plan of the multichromatic colorimeters.

completed, the observer's view should be the physical analogue of the drawing shown in Fig. 1, while fulfilling the conditions set down in this paragraph.

Fig. 2 is a schematic diagram, not drawn to scale, of the multichromatic colorimeters. The bi-partite field is indicated in the center of the diagram, the surround sphere about it, and the observer's position when viewing the bi-partite field. Small illuminants are placed in the sphere and thus control the surround of the bi-partite field. The remainder of the apparatus is symmetrical, and we shall describe only the left side.

The optical system begins with a light source, thence two condenser lenses, which, taken together, illuminate the indicated entrance slit. The entrance slit is imaged by the projection lens through a transmission diffraction grating, and thereby produces several orders of spectra. The entire spectrum projection unit is cooled by the blowers, vents and louvers specified in the diagram.

The spectra are produced by the diffraction grating in non-collimated light and some of the resolving power of the system is thereby lost. Of the several orders of spectra so produced, the first order containing the largest amount of energy is made to focus on the spectral plane while the remaining orders, including the zero order, are caught in the light traps as indicated in the diagram.

The high energy first order spectrum, after focusing on the spectral plane, impinges upon a large spherical mirror, which in turn, images the front surface of the projection lens at a position designated as the "integrated spectrum locus." The light then continues down a rod of acrylic plastic with near 100 per cent internal reflection, emerging to form one-half of the bi-partite field as seen by the observer.

Fig. 3 will further explain the workings of the multichromatic colorimeters. Suppose that we wish to produce a physical color on one side of the bi-partite field which will correspond to the energy distribution shown at the left in Fig. 3. This curve could take any shape, but we have selected this smooth, simple curve for convenience. To the right and in the upper left of Fig. 3, is a diagram of the projected spectrum as it focuses on the spectral plane, continues on to the large spherical mirror, and is recombined at the integrated spectrum locus. Considering the spectrum to be equal energy (which it is not), we could superimpose on the spectrum a black piece of paper, or template, cut in the shape of the spectroradiometric curve at the left. Under these conditions, the template will absorb, at each wavelength, the precise proportion indicated by the spectroradiometric curve. The light energy not absorbed by the template continues to impinge upon the spherical mirror, and further continues to be recombined at the integrated spectrum locus. If the spherical mirror is not off-axis, then the shape of the integrated spectrum locus is independent of the template placed on the spectral plane, since the integrated spectrum locus is an image of the front surface of the projection lens. In practice, the mirror is off-axis, and there are some color fringes formed, but these are further integrated as the light pipes down the plastic rod. Alternative methods of providing a template are specified in Fig. 3 — a structural template consisting of little slides which move up and

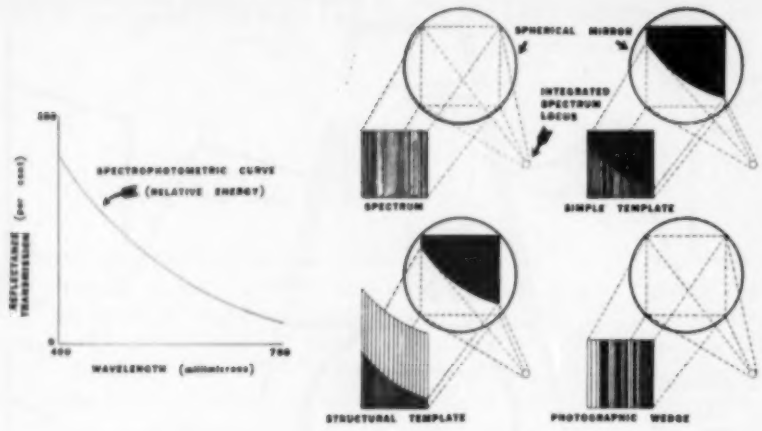

Figure 3. The use of non-adjustable, adjustable templates, and photographic wedges to produce the spectroradiometric distribution shown on the light. (Correction for instrument characteristics has not been made.)

down and a photographic wedge. It will be seen that a vast variety of spectroradiometric distributions may be simulated by the insertion of an appropriate template. The light source, of course, is not equal energy, but this may be corrected for by multiplying the desired spectroradiometric curve by a suitable correction curve.

The construction of this apparatus, then, would logically proceed in four stages. We need (a) an apparatus to project the spectrum, (b) a precision template holder to place in the spectral plane, (c) a mirror and mirror holder, and finally (d) a box to hold everything neatly, including the surround sphere.

Fig. 4 illustrates the design of the spectrum projector.* This is to be a rebuilt 2" x 2" slide projector mounted upon an adjustable milling table to permit minor focusing adjustments.** There is a reflector consisting of a highly polished heat-resistant spherical mirror, and a source which is a 1000-watt projection lamp, with medium prefocus base, designated T12. There follow two condenser lenses which illuminate a slit placed within a fabricated slit holder. The projection lens is a Kodak Ektanon f/3.5 aperture, 5-inch focal length. The diffraction grating, held by the diffraction grating holder, is a replica, 3½-inch square, has approximately 15,000 lines to the inch, and is drawn from a master by Dr. R. W. Wood.† The spectrum projector is covered, as are all parts within the instrument, with a high light absorbent surface flock.††

Fig. 5 is a photograph of the template holder which supports the templates on the focal plane. A template is shown being held in place by small clips. On this template is focused the rational spectrum produced by the spectrum projector. The effective aperture (the size of the spectrum from 400 to 700 millimicrons) is 5 inches long, and 4-$^2/_8$ inches high. These dimensions were selected for, among other considerations, graph paper commercially available so that there will be precisely one space for each 5 millimicrons and one space for each 2 per cent of intensity.* The entire unit rests upon an adjustable mounting. The motor, shown in the photograph, has no use and should be ignored.

Fig. 6 is a photograph of a first surfaced spherical mirror, 10 inches in diameter and 14 inches in focal length.** The mirror is held in a special mirror cell with push-pull screws to allow adjustment.†

It remains now to construct a box in which to house the component pieces of apparatus so that they are all in the correct relative position, one with another. The exterior housing, as it was constructed, is shown in Fig. 7. Plainly visible are the access doors and vents for supplementary cooling.†† The observer is seen viewing the bi-partite field within the surround sphere. The experimenter is shown at the control panel from whence he is able to regulate all lamp sources, running time meters, etc. Both sources and the surround illuminants are voltage regulated.‡

*Methods and devices for projecting both rational and irrational spectra are discussed at length in Gage and Gage.[9]

**Eastman Kodalide Projector, master model.

†This master is presently in the possession of Coleman Instruments, Inc., Maywood, Illinois. Replicas drawn from it are designated CY-19-A, and when used as a transmission grating, exhibit a peak just over 60% of the incident light at approximately 470 millimicrons in one first order spectrum. In the same spectrum, only 27% of the incident light is found at 700 millimicrons.

††For information concerning the methods of producing this surface (usually used as an art medium) and for sources of supply, see Nidetz.[6]

*Dietzgen graph paper, #340-12, 12 x 12 per inch.

**These mirrors were polished by Mr. Edwin F. Bailey of the Fels Planetarium of the Franklin Institute, Philadelphia. I am indebted to him and to Dr. I. M. Levitt, also of the Institute. The mirrors were silvered by the Evaporated Metal Film Corporation of Ithaca, New York.

†Made by J. W. Fecker, Inc., Pittsburgh.

††Besides the cooling fan in the base of each spectrum projector, each was cooled by two additional blowers manufactured by Small Motors, Inc., Chicago.

‡Voltage is regulated by a 2KVA Sola Constant Voltage Transformer manufactured by the Sola Electric Company, Chicago.

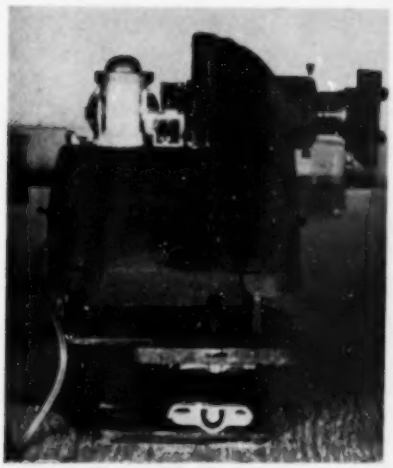

Figure 4. Photograph of the unit which projects a spectrum on spectrum plane.

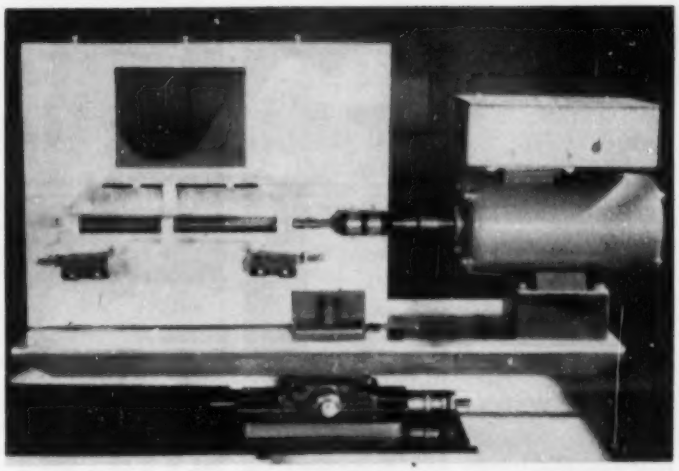

Figure 5. Photograph of the unit to hold templates on the spectral plane. A template is shown held in position by means of clips. The motor should be ignored.

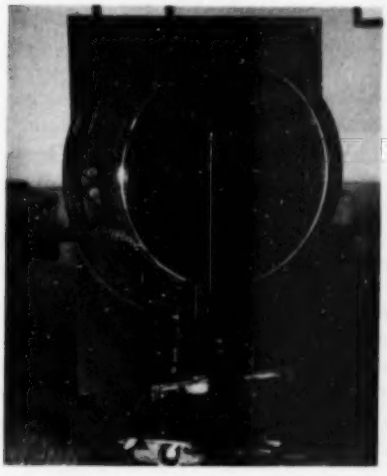

Figure 6. Photograph of the spherical mirmor, mirror cell, and cell holder.

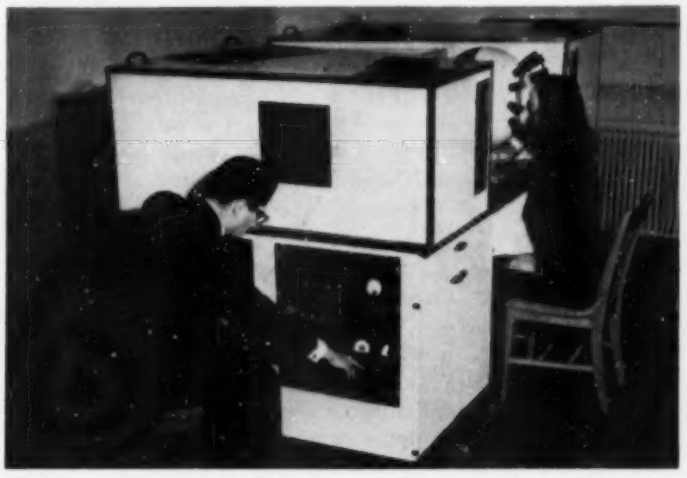

Figure 7. Photograph of the multichromatic colorimeter whose diagram is shown in Fig. 2. The observer is viewing the bi-partite field.

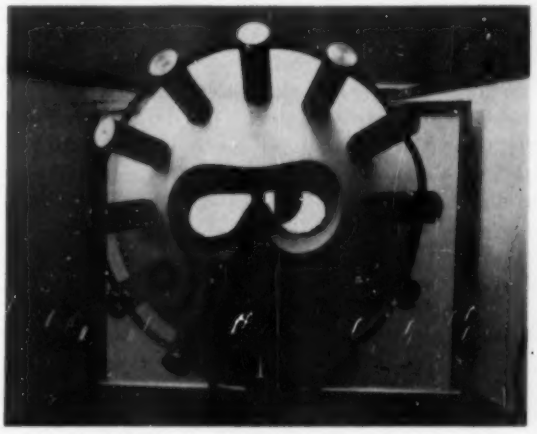

Figure 8. Photograph of the viewing sphere of the multichromatic colorimeter. The camera is off-axis to show the bi-partite field. The twelve protrusions from the sphere contain pilot lamps and filters. The lamps light up, two at a time, to evenly illuminate the surround.

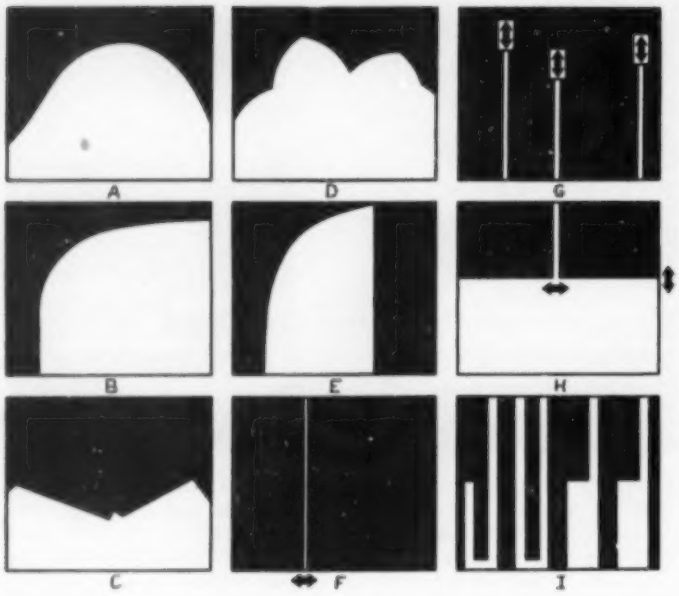

Figure 9. Example of the templates which may be used in the instrument to produce various spectroradiometric distributions. (Correction for instrument characteristics has not been made.) Templates A-B approximate distributions found in nature. Templates C-D show breaks not found in nature. Template E produces a very sharp cut-off in the red, probably not obtainable by any other method. Template F is a monochromator. Template G is a trichromatic colorimeter using three primaries. Template H is a monochromatic-plus-white colorimeter. Template I spells the name Judd — researcher in physiological optics.

Fig. 8 is a photograph of the 3½-inch bi-partite field as seen by the observer. The camera is off-axis so that the field may be seen more clearly. The sphere is 16 inches in diameter.† It is coated on the inside by high reflectance sphere paint.††

The illuminants inserted in the sphere wall are 7-watt pilot lamps in plastic cases. They light up, two at a time, through colored filters, to change the color of the surround. Color temperature of all lamps is controlled by a Variac. This bi-partite field, on either side of which we can produce any spectroradiometric distribution, is the achievement of the requirements set down in the earlier paragraphs describing the ideal instrument for research in color vision.

The number of different templates which may be inserted on the spectral plane is infinite, and nine of them are illustrated in Fig. 9. We shall disregard momentarily corrections necessary because of the light sources, etc. Templates A and B are reasonably smooth radiometric functions, could possibly be found in nature. But C is improbable for the little points would not occur. Template D also shows an erratic form which could not normally occur. Template E shows a sharp cut-off in the red never found in any physical filter. Template F is a monochromator. Template G is a trichromatic colorimeter, using any set of three primaries. Template H is a monochromatic (any wavelength)-plus-white colorimeter. Template I gives vent to the whimsy of the designer and spells out the name of an individual who has performed extensively in the field of color vision.

Calibration of the Instrument

Measurements of the instrument must show (a) the linearity of the wavelength and (b) the linearity of the intensity of radiation as a function of slit height. The instrument can be useful even if the scales are shown to be non-linear, but linearity is preferred.

We proceed first to show the linearity of the wavelength. For this measurement, we have constructed a scanning slit on the spectral plane (see Fig. 5). There is a variable speed synchronous motor* which, through a speed reducer,** drives a worm gear, as shown. The nut, meshing with the worm gear, is attached to a slit which scans the aperture on which the spectrum is focused. The beginning and end of the trace is signalled by contacts with the limit switches as shown. Change of the indicator on the control box will cause the slit to scan the spectrum in 5, 2½, or 1¼ minutes. The entire unit is mounted on an adjustable table.***

†Originally intended to be a map of the world, the sphere is pressed from steel by Replogle Globes, Inc., Chicago, Illinois.

††Sphere paint, an unusually white rubber-base paint, is used to coat the inside of photometer spheres, and is manufactured by Benjamin Moore and Company, Newark, New Jersey. I am indebted to Mr. C. H. Bryce for providing this material.

*This motor is manufactured by the Electric Indicator Company of Stamford, Connecticut. It is AC synchronous, reversible, and operates at five speeds, of which only three are of use in the present instrument.

**Manufactured by the Metron Instrument Company, Denver, Colorado.

***I am indebted to Dr. B. E. Quinn of the School of Mechanical Engineering, Purdue University, for the design of this unit.

An RCA 1P28 photomultiplier tube† was placed at the exit of the plastic rod. Appropriate voltages (regulated by careful voltage regulating circuits) are applied to the tube, and the output of the tube fed into the input of a Brown "Electronik" recorder.†† The pen of the recorder can trace the 10 inches of its excursion in 4 seconds. A full scale deflection is obtained with an input current of 6.25 microamperes. The paper movement in the recorder is made to synchronize with the movement of the scanning slit, so that a movement of the paper corresponds to a movement in wavelength. The paper can be made to move 10 inches in 5, 2½ or 1¼ minutes; synchronization is achieved by starting both a-c motors at the same time, a procedure found to give precise results.

An H-4 mercury arc lamp was then placed in the source position, and this produced a spectrum of the mercury lines on the spectral plane. The scanning slit then began its trace, and the Brown recorder traced the spikes of the lines as they impinged upon the photomultiplier tube. Fig. 10 is the actual tracing. The vertical lines drawn through each spike are positioned on the wavelength scale according to standard wavelength tables. It will be seen that the lines very closely pierce the spikes, indicating the close linearity of the wavelength scale.

†For characteristics of the photomultiplier tube see Engstrom.[8]
††Manufactured by the Brown Instrument Company, Philadelphia.

It remains now to show the linearity of intensity as a function of slit height. The slit of the scanning device was now brought to the center of the spectrum, and allowed to remain there. The light transmitted through the slit caused the recorder to make a full scale deflection. When the slit was completely covered, the pen swung to the zero position. When the slit was four-fifths covered with the piece of black paper, the pen swung to a higher position. When the slit was two-fifths covered with black paper, the needle recorded at a still higher position. This continued until the slit was completely uncovered. The result of these measurements is shown in Fig. 11 which graphs light energy as a function of slit height. The results are very close to linear, and are suitable for most work. If more accuracy is desired, the deviations may be taken into consideration. Similar results are obtained for slits placed throughout the spectrum.

Theory of Other Instruments

The scanning slit, photomultiplier tube, and Brown recorder immediately suggest spectrophotometry. The system is multiplicative only, and consists of the curves of the source, lenses, grating, mirror, acrylic plastic, *and* the response characteristic of the photomultiplier tube to give the traced response of the Brown recorder. There must always exist a reciprocal curve to the traced response.

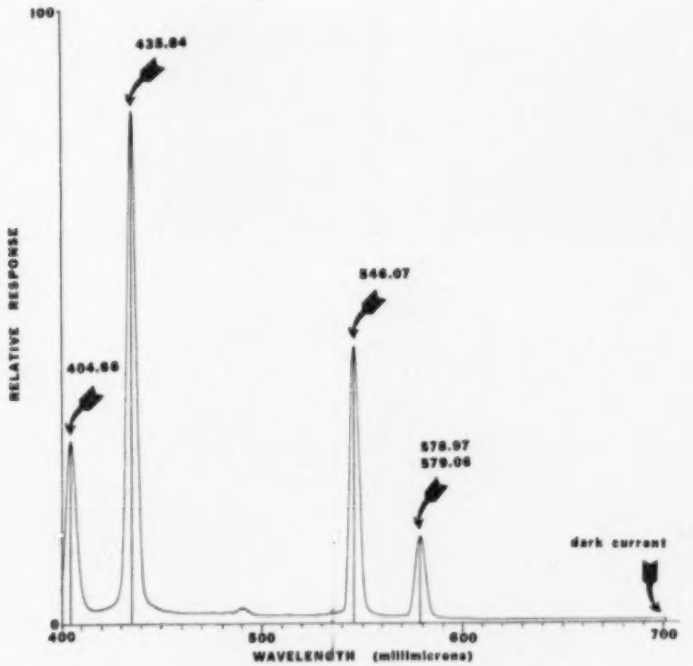

Figure 10. Automatic recording of the H-4 mercury arc lamp as detected by the 1P28 photomultiplier tube. The spikes show the positioning of the mercury lines. Deviation from linearity is given by the displacement of the top of the spike from the perpendicular line associated with it.

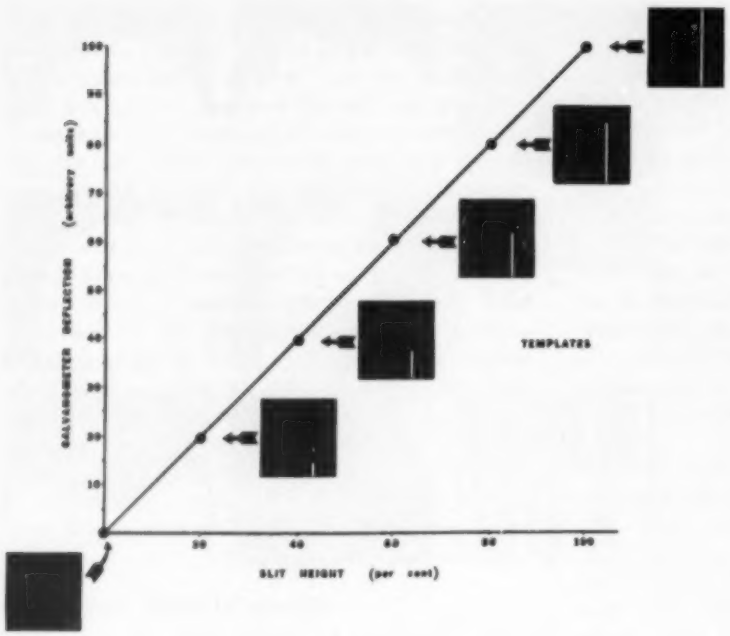

Figure 11. Plot showing monochromatic energy, detected by photomultiplier tube, as a function of slit height on the spectral plane.

If this reciprocal curve is cut as a template and placed behind the scanning slit so that the slit becomes taller and shorter as it scans, then an identity curve will be traced. Now, if an unknown filter is placed anywhere in the system, then the traced curve *will be* the curve of the unknown filter.

The apparatus further suggests an automatic trichromatic colorimeter. It is possible to adjust the response curve of the Brown recorder by adjustment of the template. A template may be cut so that the response of the Brown is, say, the $\bar{x}$ response of the C.I.E. standard observer. This may be done with precision, since the template may be recut until the response is accurate to small tolerances. Now if a filter is placed anywhere in the system, the response of the Brown will be the $\bar{x}$ curve multiplied by the spectrophotometric curve of the filter. The X of the tristimulus values associated with the filter is defined as the integral of this curve. This is obtained by removing the slit, and reading the total response of the photomultiplier tube from an ammeter (*vs.* a reading with no filter). The other tristimulus values for the C.I.E. (or any system) may be obtained in a similar manner.

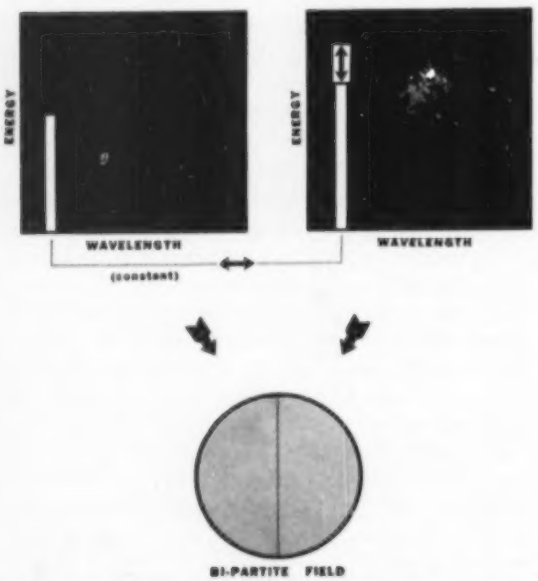

Figure 12. Examples of the application of the multichromatic colorimeters to the measurement of the photopic visibility by the cascade or step-by-step method.

Applications of the Multichromatic Colorimeters to Problems in Color Vision

It is believed that almost any problem in the psychophysics of color vision may find solution in the multichromatic colorimeters here described. As an example, we select two of the most important problems — (a) the measurement of the photopic visibility curve of the human eye and (b) the gaging of the spectrum, or what is the same thing, the measurement of the C.I.E. numbers. Wienke[37] has indicated that there are six methods of measuring this curve, and has documented 33 determinations since 1704. The six methods are (1) the

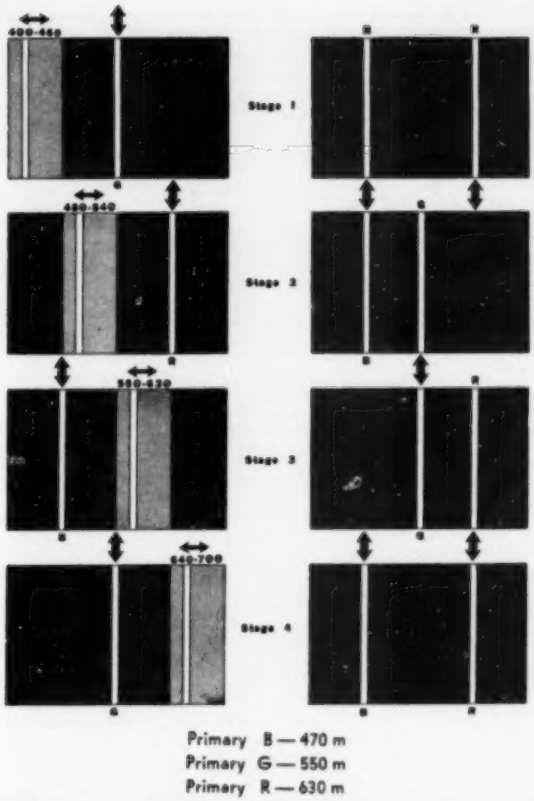

Figure 13. Example of the multichromatic colorimeters for the determination of the C.I.E. standard observer.

method of observation, (2) the equality-of-brightness method, (3) the threshold-of-vision method, (4) the cascade or step-by-step method, (5) the flicker-photometer method, and (6) the critical-frequency method. Wienke has shown that *all* of these methods may be used in the present instrument, and we reproduce as an example, Fig. 12, indicating the cascade or step-by-step method. This technique has been used by Ives,[18] Hyde and Forsythe,[15] Hyde, Forsythe, and Cady,[16] and Gibson and Tyndall.[11]

A single slit is placed on the left spectrum which allows a near monochromatic light of known wavelength to illuminate the left half of the bi-partite field. A single slit is placed on the right spectrum, which allows a near monochromatic light to illuminate the right half of the bi-partite field. The wavelength of the right side is different from that of the left, but the difference is so small that it is below the hue difference limen (in the order of three millimicrons), so that the sensations produced by these lights appear to be the same. The observer is required to adjust the height of the slit on the right spectrum so that the hues produced on the bi-partite field are metameres. Previous investigators have had difficulty in mechanical linkages, intensity controls, and wavelength determinations. Since these multichromatic colorimeters have rational spectra of large size, many of these difficulties may now be resolved.

We turn now to the technique whereby the C.I.E. numbers may be determined. Extensive gaging of the spectrum has been accomplished by König and Dieterici,[23] Abney,[1] Guild[14] and Wright.[39, 40] The last three references are the basis of the 1931 C.I.E. standard observer. Strand[35] has shown that *any* of the experimental designs of any of these investigators can be duplicated on the multichromatic colorimeters. But since the new instrument allows an infinite choice of primaries, for convenience the problem is set up as shown in Fig. 13.

We select the primaries 470, 550, and 630 millimicrons, and the investigation proceeds in four stages. In stage 1, the standard slit at the left is placed at a specified wavelength anywhere from 400 to 460 millimicrons, and the observer adjusts the heights of the three primaries (one on the left side, two on the right) until a metameric match is made on the bi-partite field. Then to stage 2, where the slit is placed at some specified wavelength between 480 and 540 millimicrons, and the observer again adjusts the primaries as indicated to establish a match. When this process is completed for each of thirty positionings of the standard slit (one at each ten millimicrons) and thus passing through the four stages indicated in Fig. 14, then the tristimulus values for these primaries will be determined and the standard observer will be established. A program for the measurement of these numbers at the University of Illinois is presently in progress.

History of the Template Colorimeters

The earliest optical system of this type described was apparently that of Kettler.[21] He used a prism as the dispersing element and a lens to collect the light after portions had been removed. He describes very simple templates.

The apparatus was again described, but not illustrated, by Maxwell.[27] In 1891, the so-called "color-patch" apparatus was described by Abney[1] and it is this source which is usually referred to as being the origin of this type of instrument. A prism is employed as the dispersing element, and a lens as a collector. The spectrum, however, had no height since the effective light source was a point and not a slit. This required that the template be a rotating disk on which the curve was cut in polar coordinates.

The color-patch apparatus was again described by Bidwell[4] but it has been modified so that the

source is a slit, and the templates need not rotate. In 1947, MacAdam[24] built a spectrum projector which integrated the projected spectrum. It utilized a diffraction grating, and a field lens as the collector.

Previous instruments were not suitable for fine colorimetric investigation because the spectra were small due to the size of the field lens used as the integrating element, and the templates devoid of accuracy. The present instrument allows a large spectrum and the accompanying precision.

Histories of instruments which include a light sensitive receiver are not included in this brief review.

Conclusions

A general theory of physical colors, and their instrument analogues, has been developed. Apparatus characteristics are derived for (1) a multichromatic colorimeter which will produce a color whose radiation content will correspond to any predetermined spectroradiometric curve including a monochromator, a trichromatic colorimeter, a monochromatic-plus-white colorimeter, for (2) a recording spectrophotometer and for (3) an integrator for the tristimulus values for any set of primaries which will give the numbers even before the recording pen begins its trace. Descriptions and calibration data of the multichromatic colorimeters are given in this paper.

Acknowledgments

Mr. Melvin Nidetz is responsible for the construction of the apparatus. I gratefully recognize his contribution.

I was assisted by Mr. Alan Strand, Mr. Richard Wienke, and Mrs. Norma Lowry Tropp. Mr. Paul Kjelshus was consultant machinist. All of these individuals are of the University of Illinois, Urbana.

I am indebted to Dr. Deane B. Judd, National Bureau of Standards, for technical aid, and to Dr. Robert E. Hopkins, Institute of Optics, The University of Rochester, for advice concerning optical computations.

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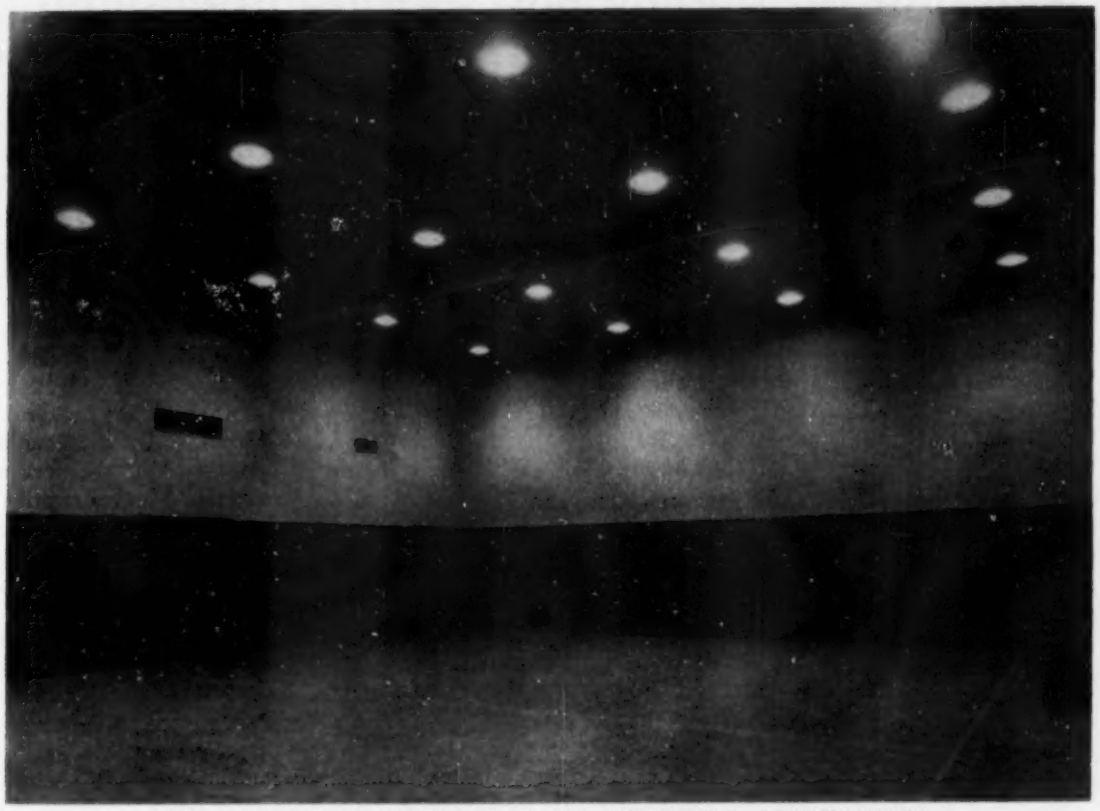

INSTALLATION AT SALVATION ARMY, HOMESTEAD, PENNSYLVANIA.

Gymnasium Lighting

LIGHTING OBJECTIVE: To illuminate a small gymnasium used for recreational purposes.

GENERAL INFORMATION: This area measures 55 x 42 feet; ceiling height is 18 feet. The ceiling is a light tan (70% RF), upper walls are plaster painted buff (50% RF), lower walls are green tile (25% RF), and the floor is gray lino-tile (30% RF). There is a small spectator area seating 50 to 70 people.

INSTALLATION: Twenty-four Guth[2]A 1716 Gym-lites are mounted on the concrete ceiling on 10½ x 9¼ foot centers. The 200-watt lamps in these units are protected as shown in the photo by a cylindrical sleeve, which also houses shielding louvers. This facilitates maintenance since there are no screens to be removed in relamping.

The initial illumination 36 inches from the floor averaged 36 footcandles; after approximately 800 burning hours it was 28 footcandles. Brightnesses at the latter time were as follows:

luminaire (on side of louver at 45 degrees)	425 ft-L
ceiling between luminaires	6 ft-L
upper wall	10 ft-L
lower wall	7.5 ft-L
floor	35 ft-L

Architect: D. Roderick Jones, Homestead, Penna.; electrician: Hodgkiss Electric Company, Pittsburgh; electrical engineer: A. G. Caplan, Duquesne Light Company, Pittsburgh.

Lighting data submitted by A. G. Caplan, Duquesne Lighting Company, Pittsburgh, Penna., as an illustration of good lighting practice and to aid in the design of similar installations.

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Lighting for Burling and Sewing (Mending)

Addendum to "Lighting of Woolen and Worsted Textile Mills"

THE FOLLOWING deals with lighting an area not treated in detail in the 1949 "Lighting for Woolen and Worsted Textile Mills." Two previous addenda to that report appeared in the October 1952 issue of ILLUMINATING ENGINEERING.

This discussion expresses one good solution to the problem of illuminating burling and sewing rooms, but variations due to the particular circumstances may be equally acceptable.

A-3. *Lighting for Burling* and Sewing.*—When the unfinished cloth comes from the looms it is inspected and knots, slubs** and pieces of yarn or foreign matter caught in the weave are removed; double or imperfect threads are removed, missing or broken threads are woven in by hand, and other weave imperfections repaired.

The work is carried out, on a special type of rack or "perch" as illustrated, by passing the cloth slowly down vertically from the overhead roll and looking through the fabric toward a linear source of light longer than the width of the cloth, removing some types of defects as they appear (Fig. 24). The cloth is then pulled down over the back roll and over the board, which is suspended at an angle of about 25 degrees from vertical, with the worker examining it as it is pulled along and correcting similar and other types of defects with the board as a background and work table (Fig. 26). Slubs, knots, double picks and foreign matter caught in the weave in white or light-color fabrics of loose weave or light in weight can be discerned more easily by through-lighting, and the imperfections are removed at that point. With darker fabrics, tight weaves and heavy weights through-lighting is often difficult and the imperfections listed above are more easily distinguished when the cloth is relatively flat on the board, or when the defect can be felt manually by passing the hand across the face of the cloth. In this latter case, the defect is found as much by feel as it is by sight; however, the relatively high level of illumination is necessary to show the nature and extent of the defect after it is located.

In sewing, as defects requiring lengthy and intricate jobs of "sewing in" are located in cloth being pulled over the board, the section of the cloth to be worked on is gathered together and pulled down and the operator works in a seated position with cloth in her lap until the repairs are completed (Fig. 27).

Through-lighting the cloth when suspended vertically from the front roll may be provided by suspending horizontally a 9000-lumen (lamp output) 60-inch fluorescent all-luminous-appearing unit 14 inches in front of the position of the vertical cloth, with the mouth of the reflector at an angle of 30 degrees from the vertical and tilted toward the cloth. Mounting height is 74 inches to bottom edge of the reflector. (See Fig. 25 for illumination levels.) No other illumination is provided for this work except general room illumination of about 25 footcandles.

For lighting cloth passing over the face of the

---

*Term derived from the French or Latin referring to a knot or lump in thread or cloth.

**Thick places in the yarn or thread.

Approved by the Council of the Illuminating Engineering Society, October 1953.

Figure 24. Inspection of cloth using through-light.

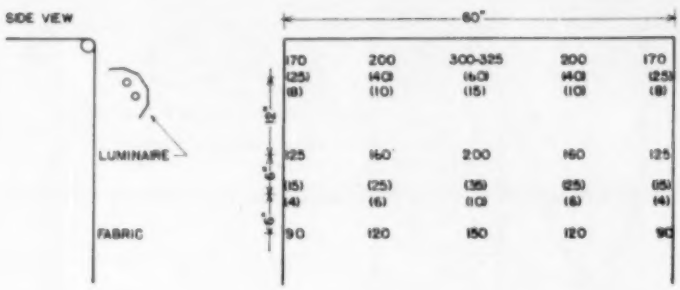


Figure 25. Illumination distribution (foot-candles) on luminaire-side of mending perch for through-lighting. The numbers in parentheses show light transmitted through cloth — the top value for loosely-woven cloth, the lower for closely-woven dark fabric.

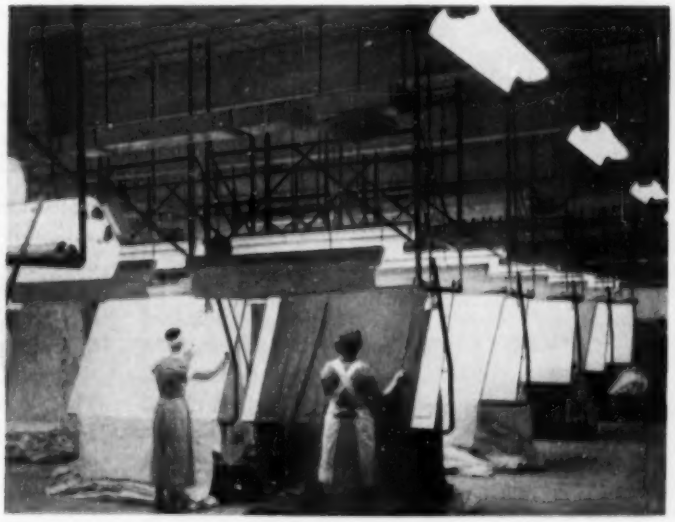


Figure 26. Burling on perch.

Figure 27. Intricate mending.

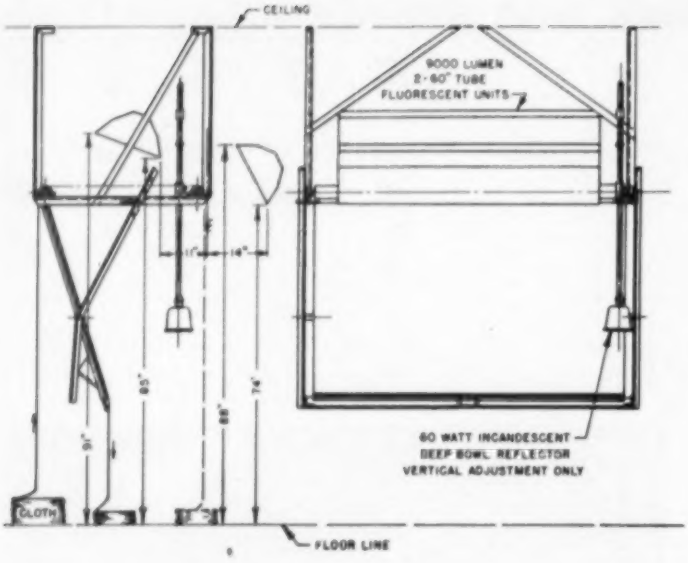


Figure 28. Recommended lighting for burling and mending.

board there is suspended horizontally 25 inches behind the fluorescent unit mentioned previously, a second 9000-lumen 60-inch fluorescent industrial unit at an angle of 20 degrees from the horizontal tilted toward the board, and mounted 85 inches from the floor. Illumination provided by light from the two units is in the order of 200 footcandles evenly distributed over the surface of the board. When through-lighting is being carried on, this second unit is turned off to allow light on one side of the cloth only.

The 60-inch luminaires recommended above assume fabric slightly less than 60 inches in width. For narrower cloth, shorter lamps will be applicable. The mounting heights suggested are those best suited to racks of the height illustrated. If rack heights are higher or lower, the height of the luminaires should be adjusted to be the same relativ height as shown here.

For "sewing in" work, carried on with operator seated and cloth held in her lap, additional illumination is provided in the installation illustrated here by a 60-watt A-19 incandescent filament lamp in deep bowl reflector mounted at the right side on a rod with vertical adjustment to allow light to be lowered, giving strong spot or flood illumination in the small area on which the operator is working. This local light is desirable for dark or heavy fabrics and for tight weaves. Illumination is in the order of 150-175 footcandles without this small unit, and 225-250 footcandles with it lighted.

I.E.S. Subcommittee on Lighting in the Textile Industry

W. L. Kelley, Jr., *Chairman*

J. M. Shute
F. J. Vorlander, Jr.
L. S. Cooke
John S. Dickson
L. A. Kline
Walter P. Rayner
Benjamin F. Roth
Carl E. Rydman
F. E. Singleton
D. Mack Woodside

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

Council Meets in New York; Summary of Action Taken

The December meeting of the I.E.S. Council was held in New York City December 10 at the Hotel Lexington. President A. H. Manwaring presided, with the following members attending: Past Presidents, S. G. Hibben and E. M. Strong; Vice-Presidents R. F. Hartenstein and D. M. Jones; General Secretary M. N. Waterman; Treasurer K. M. Reid; Directors G. W. Beals, J. S. Schuchert, C. C. Shotwell, W. A. Stannard, J. F. Whitehead, Jr., F. C. Winkler; Regional Vice-Presidents C. J. Berry, M. B. Hastings, C. C. Keller proxy for W. J. Lind; S. H. Hazleton proxy for G. E. Park, M. J. Myers, Jr., G. J. Taylor, L. C. Twichell; Executive Secretary A. D. Hinckley; Technical Director C. L. Crouch; Editor Ruby Redford; Advertising and Promotion Manager C. E. Ellis; A. A. Brainerd and R. G. Slauer.

In addition to discussion and action on Society financial affairs and other operations, Council took action on a number of pertinent matters placed before it.

Membership

Elections were approved for 20 Members, on the recommendation of the Board of Examiners. The Board also reported to Council on their election of 78 Associate Members and 7 Student Members. Following action on these elections, and with other membership changes (resignations and deaths) the current membership was shown to be the following:

September 30, 1953		December 10, 1953
7795	Total Membership	7908
32	Members Emeritus	32*
70	Fellows	69
1870	Members	1899
5579	Associate Members	5663
244	Student Members	245

The report, which was submitted by Clifford Miller, Chairman, also included recommendation for the election of Arthur B. Oday to Member Emeritus. This grade of membership was approved for Mr. Oday, in recognition of his many years' service to I.E.S. prior to his recent retirement.

A.S.P.S.L. — New Sponsor

The National Council on Schoolhouse Construction was approved as a third co-sponsor (with A.I.A. and A.S.A.) of the forthcoming revision of the American Standard Practice of School Lighting. A possible revision of the A.S.P.S.L. issued in 1948, is now under study by the School Lighting Committee.

New Sustaining Members

Action was taken on the approval of two new Sustaining Members, on recommendation of C. C. Shotwell, Chairman. Both from Canada, the new Sustaining Members are:

Black & McDonald Limited
200 King Street W.
Toronto, Ont., Canada.
Official Representative — W. J. McDonald

Zenith Electric Supply Limited
177 King Street
Toronto, Ont., Canada.
Official Representative — B. R. Steen

Publications Program

J. S. Schuchert, Publications Chairman, outlined to Council the new 1954 booklet "I.E.S. Dividends" now being prepared by his committee. The booklet will highlight the Society's services to the lighting industry including its activities in basic research, for wide distribution by the Public Relations Committee. Council approved the plans for this booklet, as outlined.

A new committee organization, as presented by Mr. Schuchert, was also approved. Under this plan, committee responsibilities will be divided jointly by R. M. Zabel, Chairman for editorial content, Eric H. Church, Chairman for data sheets (together with G. T. Anderson and Aileen Page), Henry G. Clum, changes and improvements, and John Ronayne, Chairman for publication sales.

Regional Activities

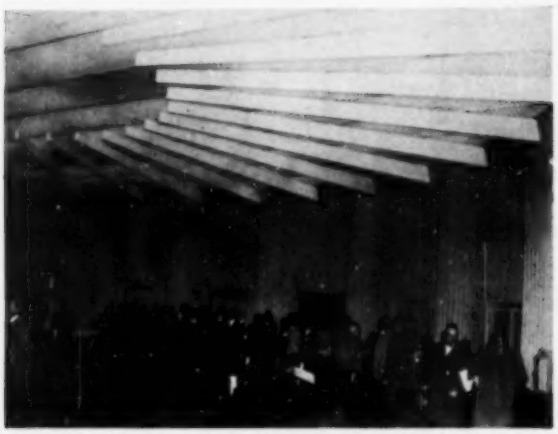
R. F. Hartenstein, Chairman of this activity told Council of a number of projects now underway regionally and locally, including details of a nationwide contest for "My Most Interesting Lighting Job." He noted also that all Regional Conferences are now set up for 1954, and some set for 1955 as well. He asked Council approval of his committee's recommendation that headquarters staff personnel attend more regional conferences.

I.E.S. Regional Conferences, 1954

Southern	Roosevelt Hotel New Orleans	April 8-9
Southwestern	Rice Hotel Houston	April 11-13
Inter-Mountain	Denver	April 15-16
South Pacific Coast	Museum of Art San Francisco	April 19-20
Pacific Northwest	Benjamin Franklin Hotel Seattle	April 22-23
Canadian	King Edward Hotel Toronto	April 28-30
Great Lakes	Sheraton-Cadillac Hotel Detroit	May 3-4
Northeastern	Hartford	Week of May 17 (one day)
Midwestern	Jefferson Hotel St. Louis	June 17-19

Here and There with I.E.S. Members

About 100 members and guests of the New England Section met November 16 at M.I.T. to hear Professor Hans Mueller speak on "Light on Light — What Is It?" Shown in the photo at left are: l. to r., Section Chairman Henry Klopot, Professor Mueller, and Program Committee Chairman William B. Elmer. In the photo at right, Section members are inspecting the lighting at the Engineering Library, which has been called the "largest fixture in the world."



Maintenance of Lighting Systems Clinic, attended by 190, was held November 18 at the Chicago Lighting Institute. A report on the clinic will be found elsewhere in Telecast.

At the Technical Committee Forum, held in Philadelphia November 12 and 13, I.E.S. technical committee chairmen exchanged views, reported on activities and heard T. W. Forbes, Technical Director of the National Research Council Committee on Highway Safety, shown in photo at left.

In the center photo, one of the I.E.S. committee chairmen reports: J. C. Forbes, Chairman of the Committee on Lighting for Civil Defense. In the photo at right, President A. H. Manwaring, Forum Chairman D. M. Jones and I.E.S. Technical Director C. L. Crouch are shown.

Each member of Council received a booklet prepared by Mr. Hartenstein, showing maps of each region, together with pictures and addresses of all Regional Vice-Presidents. This useful booklet was referred to the Publications Committee for production next year.

Technical Conference

Reporting on the final details of the 1953 National Technical Conference in New York, C. C. Keller, Conference Chairman, noted a final registration of 1007 delegates and guests, and a financially balanced operation. He commented especially on the success of the separate registration fee and banquet ticket purchase, and recommended this procedure for future conferences.

Public Relations

J. F. Whitehead, Jr., Chairman, reported a comprehensive program underway on I.E.S. public relations and information. In addition to distribution of the booklet "I.E.S. Dividends" being prepared by the Publications Committee, a broad program of Society publicity was outlined.

Conference Papers

Dr. R. M. Zabel, Papers Committee Chairman, presented his committee's progress on the technical papers sessions for the Atlantic City Conference. The tentative program plans for practical sessions on lighting design, general environment and a number of highly desirable invited papers, as well as general technical sessions.

Technical Reports Approved

Favorable letter ballot was reported, approving the technical committee reports:

"Calculating Coefficients of Utilization"

"Searchlights"

April Council in New Orleans

Letter ballot by members of Council favored the holding of the April meeting in conjunction with the Southern Regional Conference (April 8-9) in New Orleans. June Council meeting was scheduled for June 10 in New York City.

School Lighting Clinic Scheduled in New York

A comprehensive School Lighting Clinic will be held in New York City on January 28, sponsored by the New York Section of I.E.S. The Clinic, first of its kind in the New York area, will start at 1:30 p.m. on the 28th, at the Architectural Societies Building, 115 East 40th St., and continue through 9:30 p.m.

An outstanding program will feature top school lighting specialists in the currently most valuable phases of the subject.

In view of the active school building program now underway in the New York area, the New York Section's clinic is expected to offer a timely service to school planners and architects. Speakers scheduled are:

H. E. D'Andrade, General Electric Co., Moderator.

Light and Vision, C. L. Crouch, Technical Director, I.E.S.

Trends in School Architecture, Douglas Haskell, Architectural Forum.

Daylighting, Bernard Greene, Consulting Engineer.

Classroom Lighting Equipment and Layout, C. J. Allen, General Electric Company.

Miscellaneous Schoolroom Lighting and Economic Factors, John J. Neidhart, Westinghouse Electric Corp.

School Auditorium and Stage Lighting, Stanley McCandless, Century Lighting, Inc.

Michigan Section Features Industrial Lighting Forum

An Industrial Lighting Forum conducted by the Michigan Section packed the hall November 10. The meeting was a three-hour session in the auditorium of the Detroit Edison Company. Several hundred architects, contractors and industrial managers responded to the Section's invitation to hear four outstanding speakers on industrial lighting and maintenance of same, and to participate in the panel discussion which followed.

The forum discussion included:

"Ventilation, the Key to Self Maintenance," by Floyd Sell, Industrial Lighting Engineer for Detroit Edison Co.

"Maintenance and the Upward Component Luminaire," by Eric H. Church, Research Engineer for Benjamin Electric & Mfg. Co., Des Plaines, Ill.

"Group Lamp Replacement and Its Effect on Maintenance Costs," by Harry Robbins, District Engineer for General Electric Lamp Division.

"Lighting and Maintenance Problems of a Large Industrial Plant," by Edward Barringer, Chief Electrician, Micromatic Hone Company.

Lighting Design Contest For U. of Maine Students

A Lighting Design Contest is being sponsored for students of illuminating engineering at the University of Maine by the Central Maine Power Co. and the Bangor Hydro-Electric Co., as announced by Professor Kenneth L. Parsons of the university.

Speakers at a class meeting, November 18, were Raymond B. McFarland, of Central Maine Power, who explained the rules for the contest and presented the problem, and W. D. Chadeayne, of Bangor Hydro-Electric, who gave information on the professional aspects of the subject. The problem upon which the contest is based was devised by the two utilities.

Creating Pictures With Light Course at Chicago Ltg. Institute

The Chicago Lighting Institute's annual course on lighting and photography was held December 7 through December 11 at the Institute headquarters. This increasingly popular course was co-sponsored by the Chicago Camera Clubs Association. In addition to 12 lectures by photographic experts, both military and civilian, an extensive exhibit of aerial photographic equipment on loan from the U. S. Air Force, was also featured.

Lectures were given in morning and evening sessions, as follows:

Air Corps Combat Photography, by Colonel Richard W. Philbrick, Commander of the Aeronautical Chart and Information Center, United States Air Force, St. Louis, Mo.

Using the Exposure Meter, by Allen Stimson, General Electric Company, Lynn, Mass.

Providing Special Effects with Color Photography, by Gene Johnson, Eastman Kodak Co., Rochester, N. Y.

Color Photography — Indoor and Outdoor, by Gene Johnson, Eastman Kodak Company, Rochester, N. Y.

Crime Photography, by Kline Weatherford, Chief, Federal Bureau of Investigation, Chicago, Ill.

Speedlighting the Picture, by George Ward, Heiland Research Corporation, Denver, Colo.

Stereo Photography, by A. T. Lewis, David White Company, Milwaukee, Wis.

Magazine and News Photography, by Robert Garland, Graflex Corporation, Rochester, N. Y.

A General Assignment for *Life* Magazine, by Howard Sochurek, *Life* Magazine, Chicago.

Creating Pictures with Light, by Carl F. Jensen, Westinghouse Electric Corporation, Cleveland, Ohio.

A Portrait of a Queen for Sunday Features, by Eddie Johnson, Color Director, Chicago *Tribune*.

Who's Winning the Membership Campaign?

Midway scores in the membership campaign have been tallied by Ted Lauer, Membership Chairman.

Michigan Section is in first place (so far) in Group 1. In Group 2, Toronto Section is ahead. For the smaller sections and chapters, Arizona Chapter leads by quite a bit in Group 3, and San Diego Chapter is way out in front for Group 4.

Industrial Catalogs To Be Standardized

A conference on catalogs (43 persons present), conducted by the American Standards Association, has recommended that an ASA committee be created to standardize industrial catalogs, with NAPA serving as sponsor. Intent will be to develop standards of size, binding, arrangement of content and perhaps other features of the general type of catalogs commonly used by technical departments, purchasing agents, and others in industrial concerns.

Maintenance of Lighting Systems Feature of Successful Clinic

Problems involved in the maintenance of lighting systems was the unusual subject of an all day clinic, held November 18, at the Chicago Lighting Institute. Registered attendance was 190. Actually, the meeting was a Seminar on the subject, in four sessions, co-sponsored by the Chicago Lighting Institute, Chicago Section of I.E.S., Chicago Association of Commerce and Industry, and Electrical Maintenance Engineers, both Chicago and Milwaukee groups. The I.E.S. Chicago Section local committee planning the clinic was headed by Eric H. Church, as Chairman.

An enthusiastic audience, which has already requested an annual repeat, heard maintenance experts present the following program:

Morning Session

Chairman, R. J. Chapin, Superintendent of Construction & Maintenance, Marshall Field & Co.

Welcome—Carl W. Zerseu, Managing Director, Chicago Lighting Institute.

"Lighting Maintenance Pays," O. L. Bassett, Manager of Maintenance, Walgreen Company, Chicago.

"Maintenance and Selection of Light Sources," Samuel H. Eaton, Jr., Assistant District Manager, Sylvania Electric Products Inc., Chicago.

"Economics of Lamp Replacement," Alston Rodgers, Lighting Specialist, General Electric Company, Nela Park, Cleveland.

"Maintenance and Selection of Lamp Auxiliaries," (Ballast, Starters, Mercury Vapor Transformers), James H. McCulloch, Product Planner, Ballast Dept., General Electric Company, Danville, Ill.

Afternoon Session

Chairman, B. D. Allison, E.E. In Charge of Maintenance, Chicago & North Western Railroad.

"Luminaire Design as It Affects Maintenance"
(High Bay Incandescent Luminaires), J. W. Steiner, Lighting Engineer, Westinghouse Electric Corporation, Cleveland, Ohio.
(Commercial and Industrial Luminaires), Richard D. Bradley, Chief Lighting Engineer, Daybrite Lighting, Inc., St. Louis, Mo.
Finishes—Porcelain Enamel, Alzak, Paint, James R. Chambers, Sales Promotion Manager, Benjamin Electric Mfg. Company, Des Plaines, Ill.

"Maintaining the Surrounds"
(Glass Block, Skylight, Windows), Robert W. McKinley, Lighting Engineer, Pittsburgh Corning Corp., Pittsburgh, Pa.
(Walls, Ceiling, Floors, Furnishings), Thomas Moran, Chief Chemist, Luminall Paint Division of National Chemical & Mfg. Co., Chicago, Ill.

"Tools—Methods—For Easing Maintenance," Raymond Hildebrecht, Superintendent of Edison and Marquette Bldgs., Commonwealth Edison Company; David H. Mason, Lighting Consultant, Mason & Basedow, Chicago; Joseph F. Herbenar, Lighting Engineer, General Electric Company, Chicago.

"Lighting Maintenance Companies," Jerome Gimbel, President, Sun Ray Fluorescent Company, Chicago.

"Closing Remarks," Eric H. Church, Research Engineer, Benjamin Electric Mfg. Co., Des Plaines, Ill.

Of rather interesting significance is the "breakdown" of those attending in relation to professional interests. Those registered were from the following groups: Lamp companies 34; fixture and ballast manufacturers 18; building management 6; maintenance companies 2; utility representatives 9; schools 7; commercial companies 27; industrial companies 65; miscellaneous 9.

Hoover, Edison, Ford, Firestone Join Light's Diamond Jubilee

The names of Hoover, Edison, Ford and Firestone, frequently linked some 25 years ago, came together again in Light's Diamond Jubilee, it was revealed when Charles E. Wilson, chairman of the Jubilee Sponsoring Committee, announced the names of 35 committee members. Among them are ex-President Herbert Hoover; Charles Edison, son of the great inventor; Henry Ford, II, grandson of the motor magnate; and Harvey S. Firestone, Jr., son of Edison's long time friend.

The Sponsoring Committee will serve as advisers in next year's celebration of the 75th anniversary of Edison's invention of the first practical incandescent lamp, which is now being planned by the entire electrical industry.

Electrical Equipment Imports Increase

Imports of electrical machinery and equipment into this country were eleven times higher in 1952 than they were before World War II (1935-1939). U. S. exports of the same products in 1952 were only five times higher.

These figures were released recently by the National Electrical Manufacturers Association (NEMA). They are contained in a 240-page report made for the electrical manufacturing industry by the National Industrial Conference Board, business research organization with headquarters in New York. The report states that the rise of foreign electrical sales in this country in the first six months of this year was particularly sharp, running 50 per cent ahead of 1952. U. S. sales of electrical goods abroad in the same period rose only nine per cent, and actually dropped seven per cent if sales to Canada are excluded.

According to the report, foreign competition is also growing much keener and threatening further inroads in third (other) markets. Eighty per cent of foreign quotations on public bids for electrical equipment in Latin America and Asia in the past 18 months examined in the report, were lower than United States bids by an average of 20 per cent.

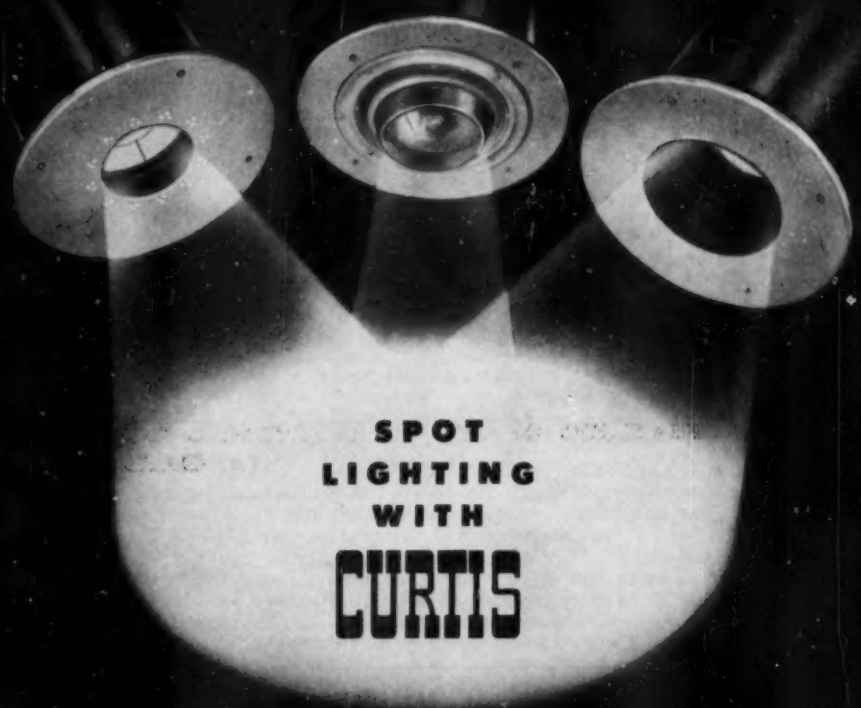
Although the Conference Board study deals primarily with trends in the electrical equipment industry, it also contains much information on general international trade, including data, charts and tables not before available for public use.

Seminar on Vision and Brightness As Reported by Interiors

A reporter from I.E.S. was not present at the recent seminar on "Vision, Brightness and Design" held at M.I.T. *Interiors* Magazine, however, sent its managing editor, John Anderson, whose amusing and comprehensive report will undoubtedly interest IE readers also. With permission of *Interiors*, IE is pleased to reproduce the following copyrighted report, as written by Mr. Anderson and published in their November issue:

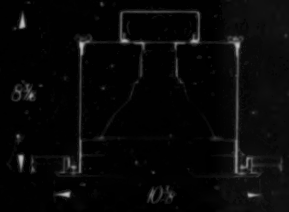
"Some 20 persons of diverse professions participated in a seminar on "Vision, Brightness and Design" in the Department of Architecture at Massachusetts Institute of Technology in late September, and frequently rewarded themselves and us with new and potent words on the subject. The trouble with most inter-professional conferences on lighting is that the usual disputants — the architect and the illuminating engineer—merely restate their same old positions with added vehemence: The illuminating engineer has his statistics marshalled to prove that the human organism, biologically speaking, reacts most comfortably (*i.e.*, reacts hardly at all) to lighting of a high level and diffuse, shadowless character, while the architect finds such evidence impeachable on the grounds that a human being is much more complicated and interesting than his biology, and that all sorts of vaguer responses — pleasurable emotions, space awareness, concepts of form — should be recognized as human satisfactions not to be ignored in planning one's visual environment. (The illuminating engineer seems to be bending; C. L. Crouch, technical director of the Illuminating Engineering Society, concurred in the general regret that most researches so far have concerned not the whole human being but only his most automatic functions.)

(Continued on page 11A)



SPOT LIGHTING WITH CURTIS

"VARI-SPOT"



CATALOG No. 2246

Curtis "Vari-Spot" is a shallow recessed downlight, utilizing one 100-watt inside frosted incandescent lamp. It is designed for use in residential and commercial interiors. An adjustable Alzak aluminum reflector permits the diameter of the circle of light to be controlled and changed as desired. Decorative holes in the finishing ring provide an attractive light pattern at the ceiling.

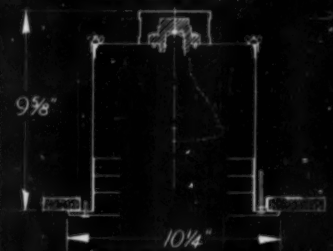
"PUNCHY"

CATALOG No. 2240

Curtis "Punchy" is a shallow recessed adjustable downlight utilizing one PAR-38, Side Prong, 150-watt projector spot or flood lamp. It is designed to provide punch lighting for counters, displays, show windows and other areas in store interiors.

"Punchy" features an exclusive aluminum gimbal ring which permits adjustment of the lamp to any angle 0° to 35° from the vertical, and 0° to 360° horizontal.

"SPOTTY"



CATALOG No. 2244

Curtis "Spotty" is a shallow recessed fixed downlight utilizing either one PAR-38 or R-40 screw base 150-watt spot or flood lamp. It has wide application for accent, supplementary and general lighting.

Three horizontal steel baffles, an integral part of each unit, are designed and positioned to provide an exceptionally low brightness incandescent unit at normal viewing angles.

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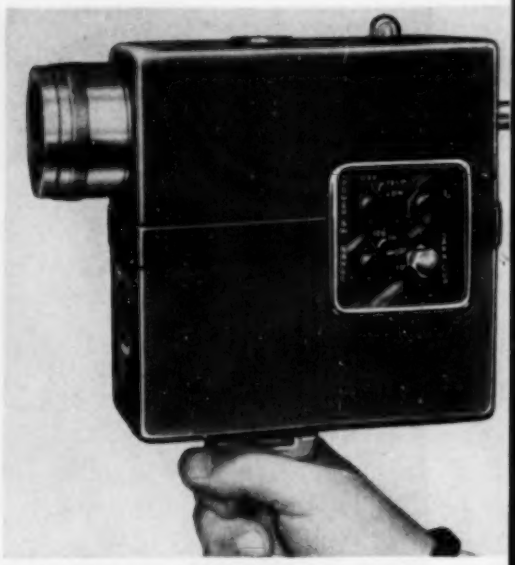

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(*Continued from page 8A*)

"The architect and interior designer is at a disadvantage in trying to convince non-colleagues that the effects he feels desirable in lighting are really so; because there is no body of evidence of popular responses, on the subtler levels, to lighting patterns, and he can do little more than express his own opinion. One of the chief functions of this conference was to find ways to conduct a research program which would objectify subjective responses to visual environment.

"The research program is being conducted in a Laboratory of Lighting Design at M.I.T., established under an initial grant from the F. W. Wakefield Brass Company, and under the direction of Professor Lawrence B. Anderson, head of the Department of Architecture. Its stated scope is 'all factors of environment which contribute to the process of seeing.' Some of the things outlined in a prospectus for study are: 'the effects of various distributions, quantities and qualities of light, heat, sound, color, and other factors of environment; and various principles of producing and controlling daylight and artificial light in relation to decoration, heating, ventilating, and acoustics.'

"While few concrete outlines of actual experiments forthcame at the conference, there was no doubt in the minds of psychologists and neurophysiologists present that research into esthetic emotions would be quite possible. Dr. Warren S. McCulloch, neuropsychologist and neurophysiologist at the Research Laboratory of Electronics at M.I.T., and one of the most remarkable men at the conference, held that pleasures *are* mensurable, and that feelings like awe, exhilaration, etc., can be isolated for examination. He was upheld by another extremely clear-headed man, Joseph C. R. Licklider, associated profesor of psychology at M.I.T. Neither offered exact methods of measuring these things (Dr. McCulloch, not joking, said the answer just could be in the tension of the toes), but they were sure that physiological responses would be not only feasible but much more reliable than verbal ones, though questions-and-answers certainly have their value too.

"As an instance of the wobbly ground one is on, even semantically, when talking about lighting, the conference began with two versions of the word 'vision,' and a third was added later. Virgil G. Casten, a Boston ophthalmologist, approaches vision, professionally at least, as the process of creating an image of things in the outside world on the retina; *i.e.*, as a simple biological fact whose test of adequacy is visual acuity, the perception of detail. Dr. Warren S. McCulloch takes a structural approach to vision, including all the lower motor mechanisms whose activities are determined much less by the retinal image than by the overall brightness patterns that strike the eye, and whose test of quality is not acuity, but human performance — posture, work output, comfort, etc. A third view, that of A. M. Skeffington, director of the Graduate Clinic Foundation in St. Louis, included much more in its concept of vision ('Vision is the total motor system, muscular system, all systems'), till all the processes of recognition and learning are lumped in.

"The most useful of these three views in discussing architectural lighting is, of course, Dr. McCulloch's; for visual responses to architectural forms occur largely in the periphery of the eye and not the retinal center. And it has been established that our first reactions to a scene are to the overall brightness patterns, and only later do we perceive forms. (An interesting experiment described by Dr. McCulloch has demonstrated that a monkey sees a larger, dimmer square to be the same size as a smaller, brighter one; the monkey re-

LIGHTING CALENDAR

Society Events

February 11, 1954—Meeting of I.E.S. Council, New York, N. Y.

April 8-9, 1954—Southern Regional Conference, Roosevelt Hotel, New Orleans, La.

April 10, 1954—Meeting of the I.E.S. Council, New Orleans, La.

April 11-13, 1954 — Southwestern Regional Conference, Rice Hotel, Houston, Texas.

April 15-16, 1954—Inter-Mountain Regional Conference, Denver, Colo.

April 19-20, 1954—South Pacific Coast Regional Conference, Museum of Art, San Francisco, Calif.

April 22-23, 1954 — Pacific Northwest Regional Conference, Benjamin Franklin Hotel, Seattle, Wash.

April 28-30, 1954—Canadian Regional Conference, King Edward Hotel, Toronto, Ont.

May 3-4, 1954 — Great Lakes Regional Conference, Sheraton-Cadillac Hotel, Detroit, Mich.

May 17 or 18, 1954 — Northeastern Regional Conference, Hartford, Conn.

June 10, 1954—Meeting of the I.E.S. Council, New York, N. Y.

June 17-19, 1954—Midwestern Regional Conference, Jefferson Hotel, St. Louis, Mo.

September 13-17, 1954—Illuminating Engineering Society, National Technical Conference, Chalfonte-Haddon Hall, Atlantic City, N. J.

Industry Events

January 11-14, 1954—National Rural Electric Cooperative Association, National Convention, Miami, Fla.

January 18-22, 1954—American Institute of Electrical Engineers, Winter General Meeting, Hotel Statler, New York, N. Y.

January 25-28, 1954—Plant Maintenance & Engineering Show, International Amphitheatre, Chicago, Ill.

March 8-11, 1954—National Electrical Manufacturers Association, Edgewater Beach Hotel, Chicago, Ill.

March 9-12, 1954 — American Management Association. General Management Conference, Fairmount Hotel, San Francisco, Calif.

March 10-12, 1954 — American Society of Mechanical Engineers, International Meeting, Del Prado Hotel, Mexico, D. F.

March 18-19, 1954 — American Trade Association Executives, Spring Meeting, Sheraton-Carlton Hotel, Washington, D. C.

April 5-8, 1954—Edison Electric Institute Sales Conference, Edgewater Beach Hotel,

May 2-7, 1954 — Society of Motion Picture and Television Engineers, Semi-Annual Convention, Hotel Statler, Washington, D. C.

May 13-14, 1954 — Public Utilities Advertising Association, National Convention, Hotel Statler, Boston, Mass.

May 17-20, 1954 — Basic Materials Exposition, International Amphitheatre, Chicago, Ill.

June 6-11, 1954 — National Association of Electrical Distributors, 46th Annual Convention, Atlantic City, N. J.

June 7, 1954, Week of — Society of the Plastics Industry, Sixth National Exposition, Cleveland, Ohio.

June 20-24, 1954 — The American Society of Mechanical Engineers, Semi-Annual Meeting, William Penn Hotel, Pittsburgh, Pa.

June 21-25, 1954 — American Institute of Electrical Engineers, Summer General Meeting, Los Angeles, Calif.

September 8-10, 1954—The American Society of Mechanical Engineers, Fall Meeting, Schroeder Hotel, Milwaukee, Wis.

September 22-24, 1954—Canadian Electrical Manufacturers Association, General Brock Hotel, Niagara Falls, Ont., Canada.

October 11-15, 1954—American Institute of Electrical Engineers, Fall General Meeting, Chicago, Ill.

October 17-22, 1954—Society of Motion Picture and Television Engineers, Semi-annual Convention, Los Angeles Ambassador, Los Angeles, Calif.

October 18-22, 1954—42nd National Safety Congress & Exposition of the National Safety Council, Chicago, Ill.

November 8-11, 1954 — National Electrical Manufacturers Association, Haddon Hall Hotel, Atlantic City, N. J.

November 28 - December 3, 1954 — The American Society of Mechanical Engineers, Annual Meeting, Statler Hotel, New York, N. Y.

nets to total flux reaching the eye, and not to shapes or sizes.) Formal qualities are the more lasting, however, and dominate our visual perceptions over any period of time.

One of the very foundations of the illuminating engineer's conceptions of a well-lighted atmosphere was shaken somewhat, on its own scientific grounds. R. D. Burnham, an illuminating engineer with the F. W. Wakefield Brass Company, clearly set forth the approach of his stripe to lighting: that a room to be illuminated with the thought of making details most easily seen, and causing no visual discomfort, should be first imagined as an empty place where light is completely diffuse, where photons simply *fill* the room. ('Like in a round can of phosphorescent paint?' asked Dr. Licklider. 'Kind of,' said Mr. Burnham.) There is complete 'randomness' and no organization at all. When you begin to put objects in the room and walls around it, you bring organization. This is the architect's job, and the illuminating engineer is not limiting him in the way he organizes the space.

"But maybe this theory of maximum entropy is not really so hot, the Doctors McCulloch and Licklider interposed, citing the incapacity to judge distances and things in the Far North, where light comes from all angles. Of course, an interior is already less chaotic than the Far North, since it *is* limited, however vaguely, even in the imagining; but still, to proclaim what amounts to sub-chaos (sub-chaos at least until the surfaces are introduced) as the starting point for the safest environment seemed open to question. But Mr. Burnham's argument did serve to bring up some clear problems of the architect, and problems which are liable to research of the sort contemplated at M.I.T. Whether or not the architect should imagine his raw interior light-flooded in the way an illuminating engineer would have it, he certainly must organize surfaces and objects to clarify that space. One of the problems suggested for study is the function of color in giving us cues as to where the walls are; colors can be legitimately used to deceive us, of course, and make a wall seem elsewhere than it is, but even then a wall should probably seem *someplace* rather than amorphous and indeterminate. Impressions of rhythms and depths, both highly influenced by lighting, were also mentioned as being susceptible to research. Gyorgy Kepes, professor of visual design at M.I.T. introduced the idea, which was greeted with enthusiasm, that modulated light might have quite satisfactory effects, recharging people's energies by recharging their environment.

"With so many things to look into, and barring more difficulties in mechanics than expected, M.I.T.'s Laboratory of Lighting Design ought to have a fruitful future."

Women Being Urged To Become Engineers

Mobilization Director Arthur S. Flemming has urged girls to enroll in engineering schools and asked the schools to recruit feminine students.

A bigger supply of women trained in science and engineering, Mr. Flemming said, not only would relieve today's manpower shortage in those fields, but might avert a crisis in the next war emergency.

Mr. Flemming has also told educators that compulsory military service will be necessary as long as the country lives "in an age of peril."

U. S. National Committee of C.I.E. Meets at Swarthmore

United States members active in the international lighting society, Commission Internationale de l'Eclairage, held their annual meeting last November 5 and 6, at the Strath Haven Inn, Swarthmore, Pa. Some 46 attended the two-day meeting. Guests attending included R. C. Sogge, President of the U. S. Committee of International Electrotechnical Commission, and Dr. H. C. Osborne, International President of the I.E.C.

Some 35 technical committees reported on the progress of their work in illumination as assigned for the past year. Of particular interest was the report of the Committee on Automobile Headlighting, which advised that a test of various auto headlight systems, both European and American, was scheduled for Detroit in May, 1954. A number of European auto lighting specialists will take part.

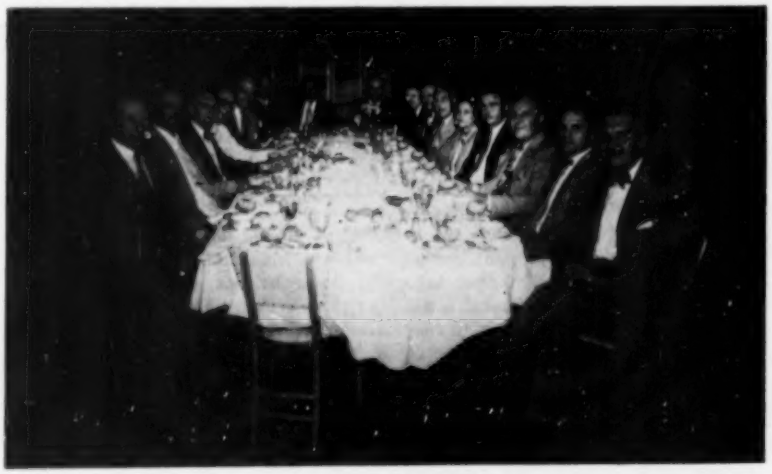
The main business of the meeting, however, was preparation for participation in the next International Session in Switzerland in 1955. This included consideration of technical committee participation papers for the conference, as well as plans for building up an effective group of delegates.

A dinner for members and guests, including a number of ladies, was held at the Strath Haven Inn the evening of November 5, with an attendance of 46. Appropriate greetings were extended by Mr. Sogge and Dr. Osborne of the I.E.C., and Mr. J. Frank Gaskill, General Sales Manager of the Philadelphia Electric Company. Speakers were Dr. Ward Harrison, President of the Commission Internationale de l'Eclairage, who also showed most interesting slides of various phases of illumination in Europe, and Mr. George E. Whitwell, Vice-President in Charge of Sales, Philadelphia Electric Company.

Carolinas Section Assists Home Ec Conference

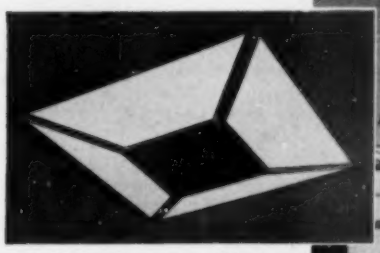
"Light for Living at Home" was featured in a panel discussion sponsored by the Carolinas Section of I.E.S., at the two-day Conference of the North Carolina Home Economics Association in Raleigh. Over 400 home ec teachers attended the meeting at the North Carolina State College.

Moderator for the lighting panel was Glenn E. Park, I.E.S. Southern Regional V-P. Presenting the demonstration with Mr. Park were Jack Welch of Duke Power Co. in Greensboro, M. L. Harkey of the General Electric Lamp Division in

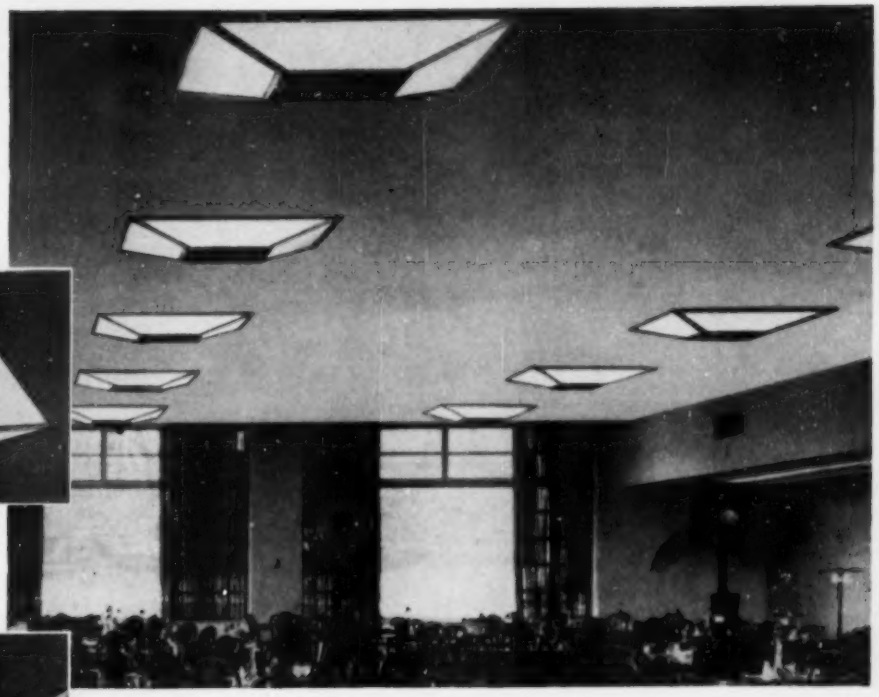


PLANNING for the 1954 National Technical Conference, to be held in Atlantic City, members of the Conference Executive Committee hold an early meeting. A. S. Turner, Committee Chairman, is on the far right.

Project: Manhattanville College, Purchase, N. Y.
Architects: Eggers & Higgins, New York, N. Y.
Fixture Manufacturer: Gruber Bros., Inc., Brooklyn, N. Y.
Lightingware: CORNING Alba-Lite and PYREX brand Lenslites



In dining room, air conditioning diffuser is integrated with lighting fixture. Light is pleasantly diffused by Corning Alba-Lite.



Classrooms, assembly hall, and corridors feature recessed fixtures also shielded with Alba-Lite low-brightness lightingware.

Stage of music auditorium is lighted with 32 recessed incandescent units shielded with PYREX brand Lenslites.

New ideas in lighting for girls' college realized with Corning lightingware

The ingenious combination of air conditioning with engineered lighting for *five* new buildings of Manhattanville College for Girls offers interesting possibilities for almost any type of building.

For example, in the dining room, air conditioning outlets are integrated in large fluorescent fixtures. Each one containing 24 lamps using a total of 600 watts. Sloping shields of Corning Alba-Lite diffusing glass afford low-brightness illumination of the proper intensity for dining.

In the assembly hall, three air conditioning outlets are spaced in each of seven rows of continuous recessed troffers. Alba-Lite is used here also. It provides diffuse, high-level illumination, free of direct glare and harsh ceiling contrast.

Over the music stage of the auditorium, 32 incandescent units are shielded by PYREX brand Lenslites effecting a wide angle cutoff of the 150-watt lamps. They create a blanket of light of high intensity.

Corning offers a wide range of diffusing lightingware as well as Lens Panels and Lenslites. You will find these products adaptable to any lighting problem. Bulletin LS -43 tells you how to figure requirements. Send for it today.

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- ☐ Corning Lightingware for Fluorescent Lighting.
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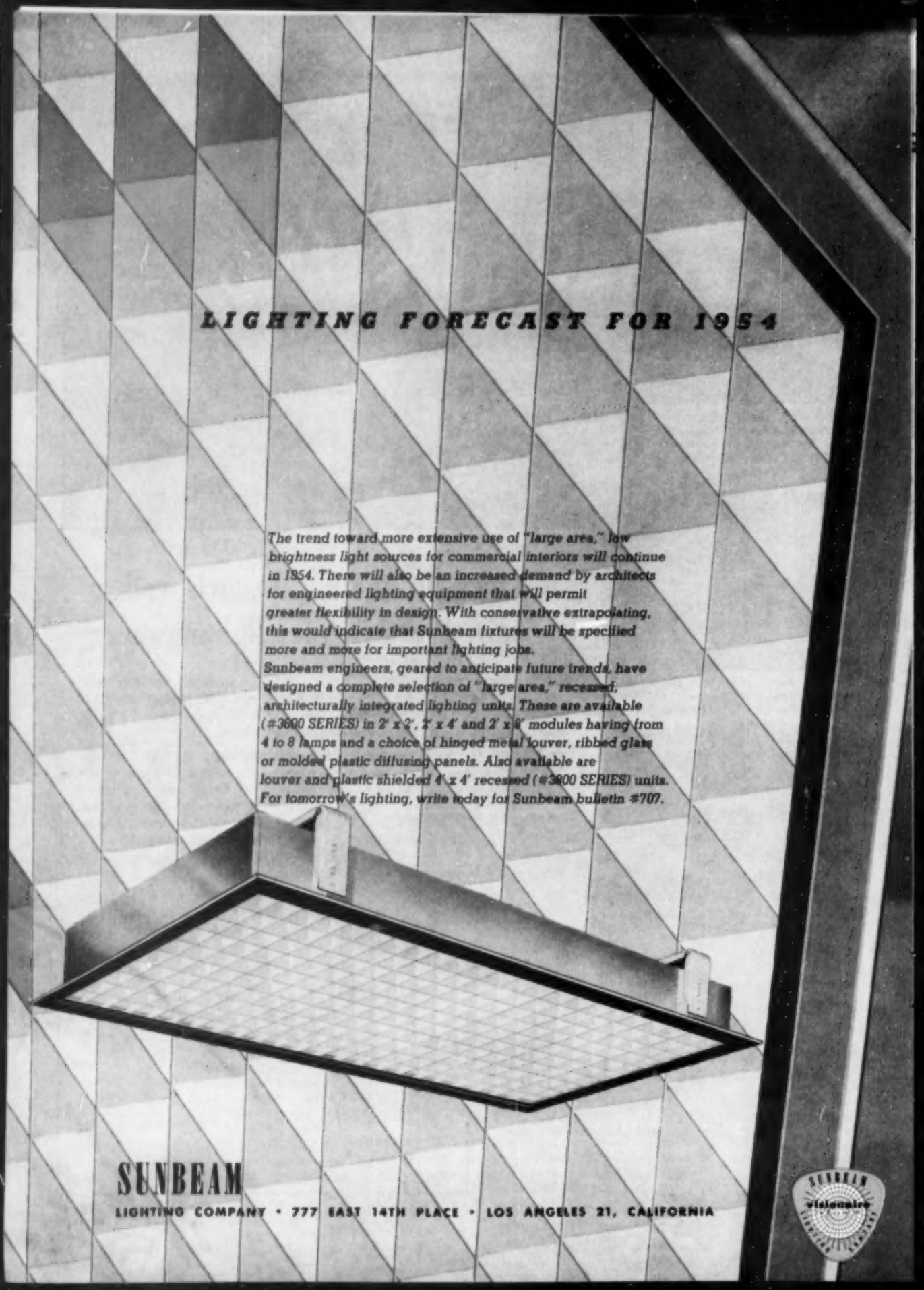
LIGHTING FORECAST FOR 1954
The trend toward more extensive use of "large area," low brightness light sources for commercial interiors will continue in 1954. There will also be an increased demand by architects for engineered lighting equipment that will permit greater flexibility in design. With conservative extrapolating, this would indicate that Sunbeam fixtures will be specified more and more for important lighting jobs.
Sunbeam engineers, geared to anticipate future trends, have designed a complete selection of "large area," recessed, architecturally integrated lighting units. These are available (#3600 SERIES) in 2' x 2', 2' x 4' and 2' x 8' modules having from 4 to 8 lamps and a choice of hinged metal louver, ribbed glass or molded plastic diffusing panels. Also available are louver and plastic shielded 4' x 4' recessed (#3800 SERIES) units.
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Charlotte, Mrs. Mildred Seaber of Duke Power Co. in Salisbury, and Coy C. Jordan of Carolina Power and Light Co. in Raleigh.

Mr. Welch presented a graphic demonstration of lighting terminology as applied to the residential field. This was followed by Mrs. Seaber's presentation of a new concept of home lighting, the lighted valance. Mr. Harkey demonstrated the many types of lamp bulbs and their uses to the home economics teachers present, and Mr. Jordan described the teaching aids available for home lighting courses in high schools.

Lighting Design Problems Course Given by Inland Empire Chapter

A four-week course in Lighting Design Problems was held last month in Spokane, Wash., sponsored by the I.E.S. Inland Empire Chapter. Aimed at all who are associated with the lighting field — designers, architects, jobbers, salesmen or contractors, the course consisted of actual application design problems to be solved by the class.

Topics and speakers were:

Friday, November 20

Light Sources—W. C. Hird, Westinghouse Lamp Division.

Fixture Design Evaluation — Blair Plowman, Washington Water Power Co.

Tuesday, November 24

Store Lighting—Hal Gardner, Columbia Electric & Mfg. Co., Seattle, Wash.

Industrial Lighting and Floodlighting—Paul Davis, Holophane Co.

Tuesday, December 1

Office Lighting — David C. Moses (Chapter Chairman), General Electric Supply Corp.

School Lighting — Joseph Doyle, Consulting Engineer.

Friday, December 11

Panel Discussion of questions from the class —Panel Leader, Richard Harbour, Professor of Electrical Engineering Department, State College of Washington.

Classes were held in the Lecture Room of the Engineering Building of Gonzaga University. A nominal registration fee of $2.00 covered all four sessions.

Residence Lighting Course To Be Given in New York

Announcement has been made of an eight-session course on Lighting Residential Interiors to be presented under the auspices of the New York Residence Lighting Forum during February and March. The course will deal with basic principles of residential lighting and the best current practice, and is planned to be of practical value to decorators, designers, architects, lighting consultants, and all who are interested in the home environment, either professionally or as homemakers.

The schedule is as follows:

February 3

Lighting for Living—Gladys Miller, Decorator and Consultant.

February 10

The Language of Lighting—Priscilla Presbrey, Westinghouse Electric Corp.

The Relationship Between Light and Vision—C. L. Crouch, Technical Secretary, I.E.S.

February 17

Portable Lamps—Types, Design, and Applications—Lucy L. Hanan, Consolidated Edison Company of N. Y., Inc.; William F. Blitzer, Lightolier, Inc.

February 24

Ceiling- and Wall-Mounted Fixtures—Types, Design, and Applications — Lillian Eddy, General Electric Company.

March 3

Recessed Fixtures—Gene G. Rae, Holophane Company, Inc.

Built-In Equipment—Edith Buchholtz, Westinghouse Electric Corp.

March 10

Lighting for Specific Visual Tasks—Lillian Eddy, General Electric Company.

March 17

Color and Light—Jan Reynolds, Sylvania Electric Products, Inc.

Coordinating Lighting and Decoration—Melanie Kahane, Decorator.

March 24

Lighting for Decorative Accent and Special Effects—Thomas Smith Kelly, Lighting Engineer and Consultant.

General Review and Discussion of Problem Solutions—Edith Buchholtz, Westinghouse Electric Corp.

Meetings will be held in the General Electric Auditorium, 570 Lexington Avenue, New York, from 7:00 to 9:00 p.m. Registration fee is $5.00 for Forum and I.E.S. members, $7.50 for non-members. Further information and registration blanks may be obtained from Miss Jean Fowler, Long Island Lighting Company, 1501 Franklin Ave., Mineola, New York.

Although four previous residence lighting courses have been presented by the New York Forum since 1948, two in cooperation with the Division of General Education of New York University and two independently, none has been given in the last two years. The Education Comittee in charge of the project includes Miss Lillian Eddy, Miss Jean Fowler, Miss Lucy Hanan, Miss Ruth Lieb, Miss Gladys Miller, Miss Winonah Murphy, Mr. Gene G. Rae, and Miss Priscilla Presbrey, Chairman.

I.E.S. National Technical Conferences

September 13-17, 1954 — Chalfonte-Haddon Hall, Atlantic City

September 12-16, 1955 — Statler Hotel, Cleveland

September 16-21, 1956 — Statler Hotel, Boston.

ABOUT PEOPLE

Lawrence S. Harrison, Consulting Engineer of the Metropolitan Museum of Art, New York City, has resigned staff responsibilities with the Museum and has been granted retirement. The Trustees of the Museum have elected him an Honorary Fellow for Life. Mr. Harrison, who was formerly with the General Electric Co. and International Business Machines Corp., joined the staff of the Museum in 1940 to develop requirements, coordinate planning and direct construction of the Museum's long-range reconstruction program, the first stage of which has been completed. During retirement, Mr. Harrison will devote himself to research and part-time consulting work in the lighting and allied fields.

John Findley Peters, consultant with Westinghouse Electric Corp., has been awarded the Edison Medal for 1953 by the American Institute of Electrical Engineers. The award was made "for his contributions to the fundamentals of transformer design, his invention of the Klydonograph, his contributions to military computers and his sympathetic understanding in the training of young engineers."

Henry E. Bachman has been named supervisor of manufacturing engineering at the Westinghouse Lamp Division's fluorescent lamp plant at Fairmont, W. Va. Mr. Bachman was formerly a section engineer at the company's Bloomfield, N. J. offices.

C. A. Fike has been appointed manager of manufacturing at the Cleveland, Ohio, plant of Westinghouse Electric's Lighting Division. Mr. Fike assumes his new post after service as superintendent of manufacturing in Cleveland.

The Florida Chapter of I.E.S. has appointed **A. D. Wallace,** Florida Power Corp., St. Petersburg, as Vice-Chairman of the Chapter to fill the unexpired term of **Jeff Faulkner,** General Electric Lamp Division, Jacksonville.

Pittsburgh Corning Corp. has opened a branch sales office at 57 Bloor St., West, Toronto, Ont., and has appointed **E. H. Martin, Jr.,** as district manager. Mr. Martin was formerly manager of Foamglas low temperature insulation sales.

Harry A. Miller has been appointed Texas sales representative for Abolite Lighting Division of Jones Metal Products Co., with his headquarters at 1925 Cedar Springs Ave., Dallas.

(Continued on page 17A)

when the finest in lighting is specified...

Installations of Smithcraft Area Illumination the country over vary greatly as to size, pattern, shielding, periphery and shielding. And it's this *flexibility of design* that makes this advocated overall lighting system an important new architectural concept. All Smithcraft Area Illumination installations have these things in common: superb quality of illumination; functional integration with the building structure; ease and efficiency of installation and maintenance.

Reading from left-to right, starting at top.

The Mennen Company, Morristown, New Jersey
Owens-Corning Fiberglas Corp., Ashton, Rhode Island
Ford Motor Company, Dearborn, Michigan
Melbourne National Bank, Melbourne, Florida
Niagara Mohawk Power Corp. Syracuse, New York
Rawding Electric Company,
Beaver Falls, Pennsylvania
Texas Eastern Building, Shreveport, Louisiana
Mount Healthy-Saving and Loan Company,
Mt. Healthy, Ohio
Van Huffel Tube Corporation, Warren, Ohio
Florida Power and Light Company, Sanford, Florida

smithcraft **area** *illumination*

Smithcraft
LIGHTING DIVISION
CHELSEA 50, MASSACHUSETTS

(*Continued from page 15A*)

Garcy Lighting, Chicago, has appointed **B. L. Cook**, of Houston, Texas, as its representative in the Gulf Coast area of Texas.

Liteecraft Manufacturing Corp., New York, N. Y., announces the appointment of **Joseph A. Tills** as Mid-West Sales Manager. Mr. Tills has headquarters in Chicago, Ill.

The Electro Silv-A-King Corp., Chicago, announces the appointment of **George Stallman** as District Sales Manager for their Seattle District, comprising the states of Oregon and Washington. Mr. Stallman, who will make his office at 568 First Avenue South, Seattle, Wash., is known on the West Coast through his activities as sales representative for a number of manufacturers as well as for his position during World War II as U. S. Army "Dim-Out" Control Consultant in the Southwest Washington district.

Globe Lighting Products, Inc., of New York and California, announces the appointment of **Ed Skillman** as Sales Promotion, Advertising and Merchandising Manager. Mr. Skillman's former experience has been as National Committee Executive Secretary for the National Association of Manufacturers, Eastern Promotional Executive for the National Metal Trades Association and positions in industry as sales and advertising manager.

NEW MEMBERS

At the meeting of the I.E.S. Council held in New York, N. Y. on December 10, the following were elected to membership. Names marked * are transfers from Associate Member grade.

ARIZONA CHAPTER

Associate Members:

Gasperak, F. M., Arizona Public Service, Phoenix, Ariz.
Gross, Joe, Gross Electric Co., Phoenix, Ariz.
Quillen, I. H., Jr., Newbery Electric Corp. of Ariz., Phoenix, Ariz.
Walton, M. J., Regal Lighting Fixture Co., Phoenix, Ariz.
Williams, J. R., Arizona Public Service Co., Phoenix, Ariz.

CAPITAL SECTION

Member:

Hemker, W. S., General Electric Co., Richmond, Va.

CENTRAL NEW YORK SECTION

Members:

Kurtz, P. E., Jr., Cedric R. Acheson, Consulting Engineer, Syracuse, N. Y.
*Parsons, W. H., N. Y. State Electric & Gas Corp., Binghamton, N. Y.

CHICAGO SECTION

Member:

Pallagi, J. E., Anderson & Pallagi, Chicago, Ill.

Associate Members:

Brazinski, Charles, Benjamin Electric Mfg. Co., Des Plaines, Ill.
Hitchcock, C. L., Englewood Electrical Supply Co., Chicago, Ill.
Lee J. E., Jefferson Electric Co., Bellwood, Ill.
Wosniak, R. E., Chicago Lighting Institute, Chicago, Ill.

CLEVELAND SECTION

Associate Member:

Churchill, R. D., General Electric Co., Cleveland, Ohio.

EASTERN NEW YORK CHAPTER

Member:

Hamm, R. S., Reisner & Urbahn, Troy, N. Y.

EASTERN PENNSYLVANIA SECTION

Associate Members:

Hauer, R. M., Metropolitan Edison Co., York, Pa.
Knight, R. W., 150 Maple Ave., Holmes, Pa.
Schmehl, B. C., Metropolitan Edison Co., Reading, Pa.

FOREIGN NON-SECTION

Member:

Carroll, J. J., Apartado Postal No. 3145, Caracas, Venezuela.

GEORGIA SECTION

Associate Members:

Forst, A. M., Jr., Rich's Inc., Atlanta, Ga.
Starr, F. J., Starr Electric Co., Macon, Ga.

HEART OF AMERICA SECTION

Member:

*Kobrock, C. H., Kansas City Terminal Railway Co., Kansas City, Mo.

Associate Members:

Albin, H. W., Kansas Gas & Electric Co., Newton, Kans.
Hartford, J. H., Kansas Gas & Electric Co., El Dorado, Kans.
Likes, N. W., Midwest Chandelier Co., N. Kansas City, Mo.
Manchester, D. J., General Electric Co., N. Kansas City, Mo.
Vaughn, L. M., Kansas Gas & Electric Co., Independence, Kans.
Walter, A. J., General Electric Co., N. Kansas City, Mo.
Ward, A. C., Kansas Gas & Electric Co., Arkansas City, Kans.

INDIANA SECTION

Member:

*Rowe, R. F., General Electric Co., Ft. Wayne, Ind.

INLAND EMPIRE CHAPTER

Associate Member:

Needham, A. C., Washington Water Power Co., Coeur d'Alene, Idaho.

IOWA SECTION

Associate Members:

Larson, Lee, Revere Electric Mfg. Co., Davenport, Ia.
Wilson, J. R., Iowa Illinois Gas & Electric Co., Iowa City, Ia.

MARYLAND SECTION

Member:

*Morgan, Lee W., The Potomac Edison System, Hagerstown, Md.

MEXICO CHAPTER

Associate Member:

Alonso L., Juan, Philips S. E. T., Mexico, D. F.
Cuenca Millan, Luis, Mitla #18, Mexico, D. F.
Garcia H., R., General Electric S. A. de C. V., Guadalajara, Jalisco, Mexico.
Montano Ch., Francisco, Industria Montaenz S. R. L., Tajin #308, Mexico, D. F.
Wadsworth, G., Jr., General Electric S. A., Mexico City, D. F.

MICHIGAN SECTION

Associate Members:

Chartier, K. J., Westinghouse Electric Supply Co., Detroit, Mich.
Ehrler, E. R., Gray Electric Co., Detroit, Mich.
Ervin, R. S., Ervin Electric Co.—Ervin Industrial Control Co., Saginaw, Mich.
Hess, V. M., Ballard Electric Co., Pontiac, Mich.
Hoste, J. A., Motor City Electric, Detroit, Mich.
Jarocha, William, Hall Engineering, Detroit, Mich.
Long, Gordon, Long Electric Co., Detroit, Mich.
Schaibley, W. F., W. F. Schaibley Co., Detroit, Mich.
Schives, Clarence, Gray Electric Co., Detroit, Mich.
Stauss, W. J., Consumers Power Co., Jackson, Mich.
Webb, Jerome W., Crescent Electric Co., Detroit, Mich.

MID-SOUTH CHAPTER

Members:

Cratin, P. F., Corps of Engineers, U. S. Army, Little Rock, Ark.
Blaylock, R. E., Blaylock & Zander, Little Rock, Ark.

Student Members:

Child, E. P., Southern College of Optometry, Memphis, Tenn.
Clark, J. E., Southern College of Optometry, Memphis, Tenn.
Mills, J. A., Southern College of Optometry, Memphis, Tenn.
Walraven, L. L., Southern College of Optometry, Memphis, Tenn.

MILWAUKEE SECTION

Member:

*Blackford, W. F., Line Material Co., S. Milwaukee, Wis.

MONTREAL SECTION

Associate Members:

Carignan, Marcel, The Shawinigan Water & Power Co., Victoriaville, Que.
Carpentier, Jean, The Shawinigan Water & Power Co., Ste. Therese, Que.

NEW ENGLAND SECTION

Associate Members:

Hale, Robert L., Western Mass. Electric Co., Greenfield, Mass.
Holden, D. Y., Central Maine Power Co., Rockland, Maine.
Holzman, Bernard, Foster Wheeler Corp., Boston, Mass.
Moot, J. R., Marlux Corp., Somerville, Mass.
Nitardy, Carl, A. L. Smith Iron Co., Chelsea, Mass.

NEW MEXICO CHAPTER

Member:

*Roughton, B. G., State Electric Supply Co Inc., Albuquerque, N. M.

NEW ORLEANS SECTION

Associate Member:

O'Neill, J. H., Louisiana State Board of Health, New Orleans, La.

NEW YORK SECTION

Members:

Bates, W. C., Jr., Westinghouse Electric Corp., New York, N. Y.
Fread, Bernard, Medical College, N. Y. U., New York, N. Y.
Spiegel, George, Ebasco Services Inc., New York, N. Y.

Associate Member:

Peterson, S. K., Rambusch Decorating Co., New York, N. Y.

Student Member:

Brophy, M. F., Columbia University, New York, N. Y.

NORTHERN CALIFORNIA SECTION

Member:

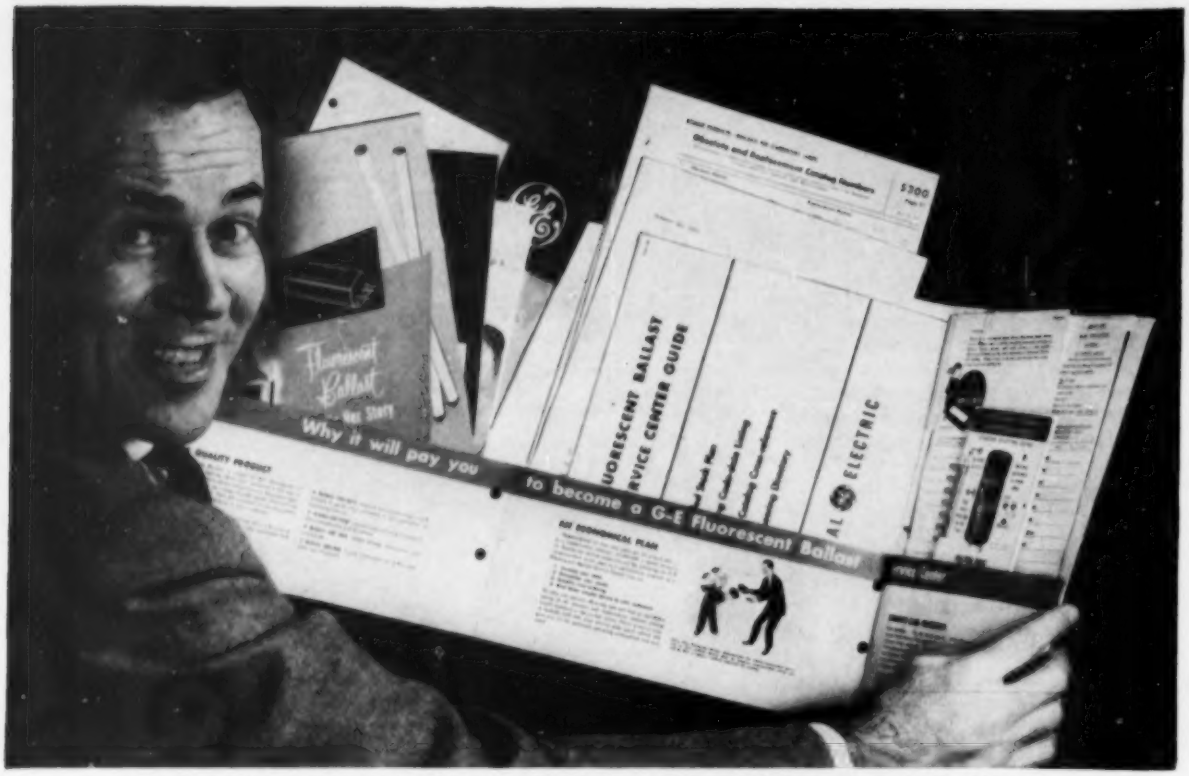
*Wright, H. A., 225 Kearny St., San Francisco, Calif.

OREGON SECTION

Student Member:

Boling, W. L., Oregon State College, Corvallis, Ore.

(*Continued on page 31A*)



Here's the complete kit furnished to your distributor to solve your ballast replacement problems.

New G-E Service Center Plan streamlines ballast replacement for fluorescent users

Mr. Wholesaler: The biggest promotion in the ballast business is ready to help you get your share of the growing replacement ballast market. Ask your G-E representative for the details about the ballast service plan.

Immediate in-warranty ballast replacement now possible at wholesaler's place of business.

There's good news for you in the new General Electric Ballast Service Plan for lighting equipment wholesalers. Now your fixture customers get immediate replacement on G-E ballasts which fail within warranty. There's no red tape on the ballast exchange. G-E Ballast Service Centers are authorized to make free replacements right-off-the-shelf of G-E ballast which fail within warranty. And the same ballast stocks are available for normal ballast replacements, too.

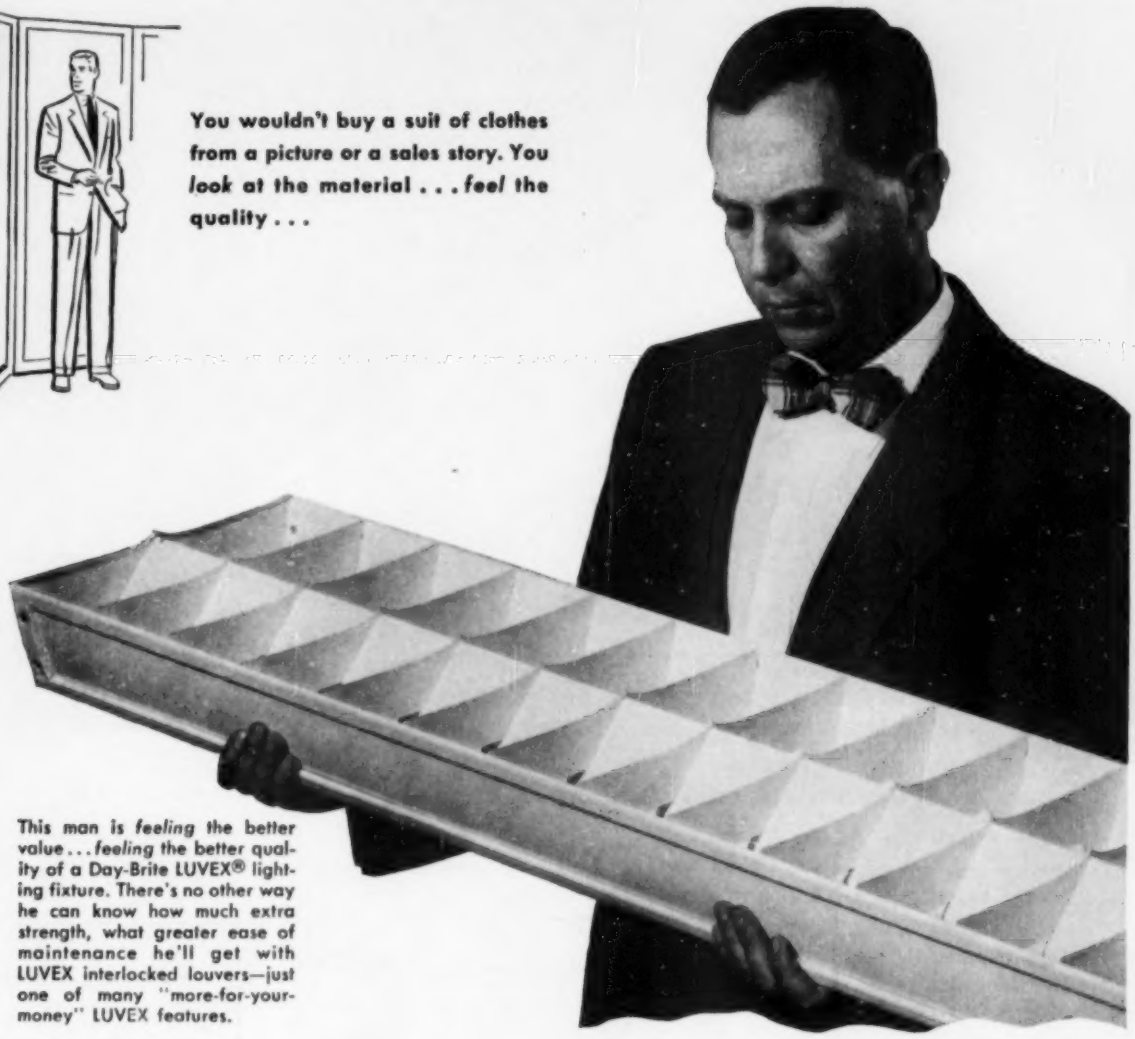
Under the new plan, your distributor gets the latest information on how ballasts work, how to install and test them, and other aids designed to help with lighting problems.

If your distributor hasn't yet heard about the new G-E Ballast Service Center Plan, show him this ad. And for more information on the new program, contact your nearby G-E Apparatus Sales Office. General Electric Co., Schenectady 5, N. Y. 401-3

Progress is our most important product

GENERAL ELECTRIC

You wouldn't buy a suit of clothes from a picture or a sales story. You *look* at the material . . . *feel* the quality . . .



This man is *feeling* the better value . . . *feeling* the better quality of a Day-Brite LUVEX® lighting fixture. There's no other way he can know how much extra strength, what greater ease of maintenance he'll get with LUVEX interlocked louvers—just one of many "more-for-your-money" LUVEX features.

HOW TO PROTECT YOURSELF

when you buy lighting fixtures

Buy lighting fixtures like you buy a suit of clothes. Look at them yourself . . . *feel* the value . . . *feel* the quality . . . *feel* the difference you can't always find in the sales stories.

Pictures and sales stories are excellent ways to bring competitive lines of fixtures to your attention.

But when you're ready to invest your money, *don't buy until you handle the fixtures yourself.* Don't buy until you're satisfied by your own inspection which fixture is *your* best buy.

We expect you to test the LUVEX (or any other Day-Brite fixture) in exactly that way. We know from experience your own judgment is the very best Day-Brite sales story we have.

LOOK AT THE LUVEX®. . . FEEL THE DIFFERENCE . . .

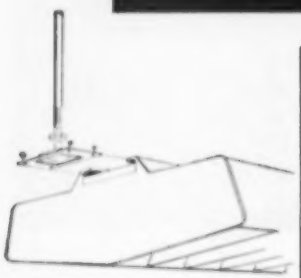
DECIDEDLY BETTER
DAY-BRITE
Lighting Fixtures

BEFORE YOU BUY!

Day-Brite Lighting, Inc., 5432 Bulwer Ave., St. Louis 7, Missouri
In Canada: Amalgamated Electric Corp., Ltd., Toronto 6, Ontario

45

Performance Exceeds Requirements of American Standard Practice for School Lighting



Sliding stem plate can be moved from end to end to support the Cavalier at any point, completely eliminating problems of in-line spacing of mounting points.

For the complete story of this beautiful new streamlined direct-indirect luminaire, write for an 8-page 3-color folder. The F. W. Wakefield Brass Company, Vermilion, Ohio. In Canada, Wakefield Lighting, Ltd., London, Ontario.

Note that the brightness readings for the new Cavalier are well below the recommended maximums:

Zone	The Cavalier	Max. Recommended with Proper Refl.
60°–90°	100 ft.-L	450 ft.-L
45°–60°	250 ft.-L	900 ft.-L
0°–45°	1800 ft.-L	2000 ft.-L

Several important new design features are responsible for such excellent performances:

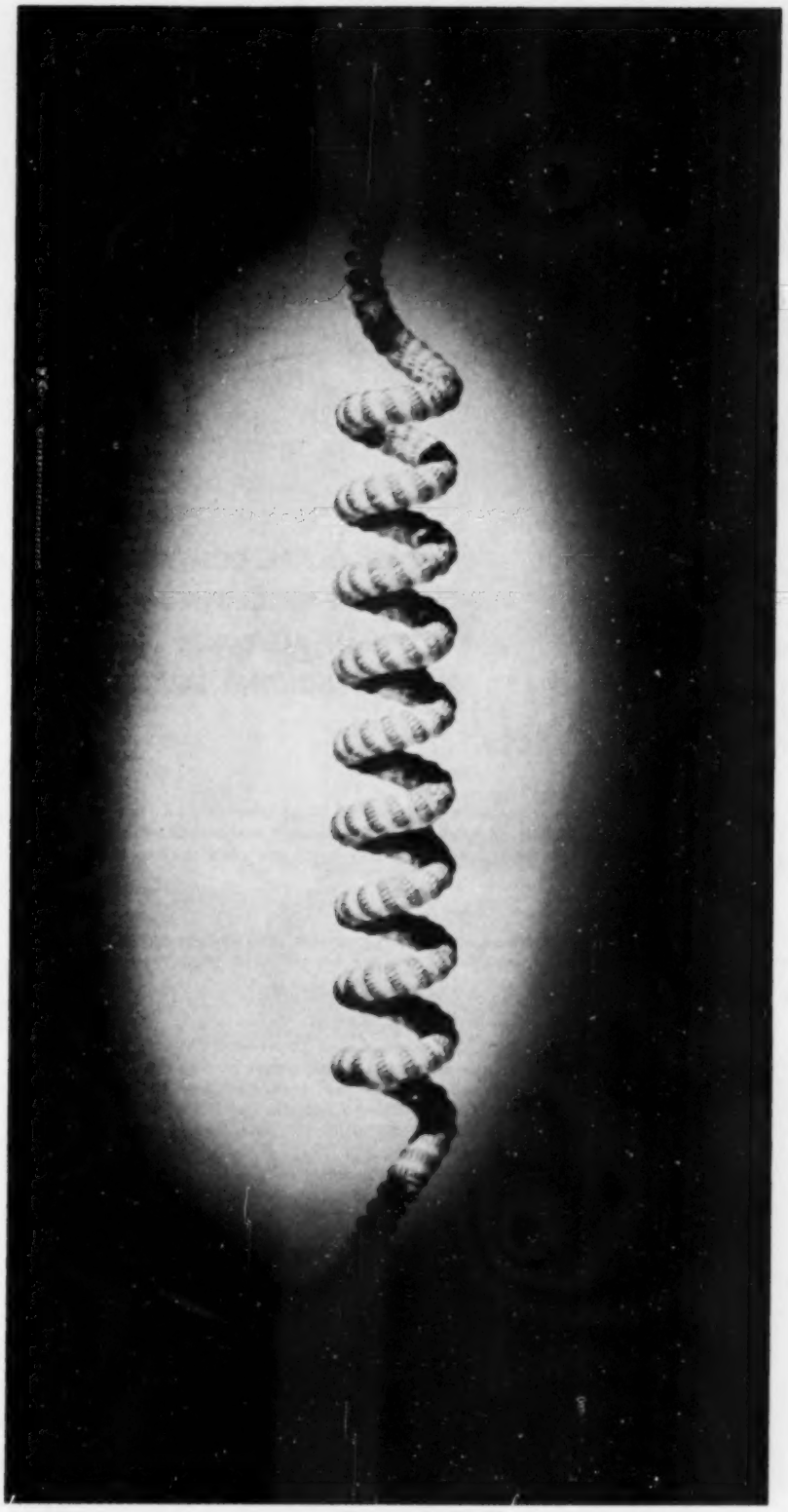
FIRST, the full length luminous plastic side panels have no opaque metal framing, but are supported internally by a steel frame. This frame is also an internal reflector, a feature which keeps side panel brightness down to a pleasant 100 ft-L.

SECOND, the louvers provide complete 45° x 45° shielding, or shielding at 45° x 25°. There is no view of lamp at specified shielding angles through the entire viewing cone.

THIRD, a special Wakefield low-brightness finish on louvers, side reflectors, panels and channels serves to keep brightness low.

Here then is an excellent new direct-indirect luminaire for your consideration when planning classroom lighting. There are two models, both equipped for Rapid Start or Slimline lamps, the Cavalier II (two lamps) and the Cavalier IV (four lamps).

Wakefield Over-ALL Lighting



New twist on old idea makes G-E fluorescent lamps last longer

ONE of the most important materials in a fluorescent lamp is the little bit of chemical at each end of the tube. The current flows through it, electrons flow out, and the lamp starts to glow.

The old idea was to hold the chemical on a double-twisted wire coil. General Electric's new idea was to go that one better: give the wire a *triple* twist. This not only holds more chemical, it also holds it longer.

The result of course is longer lamp life and more light for your money.

General Electric's triple coil is used in G-E slimline and other G-E instant-start lamps. Just one more example of why...

You can expect the best value from General Electric fluorescent lamps

You can put your confidence in—

GENERAL ELECTRIC

ALL-PURPOSE INCANDESCENT DOWNLIGHTS

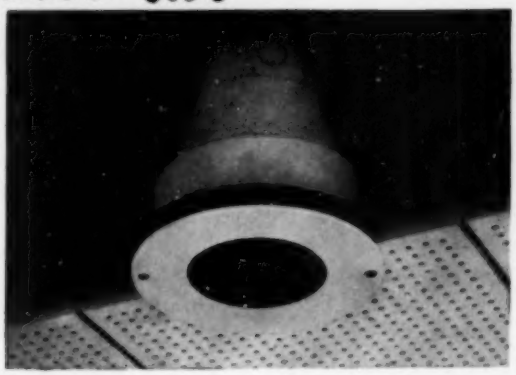
Designed to

PROVIDE MORE LIGHT

AT LOWER OVERALL FIXTURE COST

WITH HIGHER MAINTAINED EFFICIENCY

Silver-dot



Silver-spot

with . . .

BETTER GLARE CONTROL

EASIER RELAMPING

THAN ALL OTHER

RECESSED LIGHTING DEVICES

SILVER-SPOT DISTRIBUTION

SILVER-DOT DISTRIBUTION

HERE ARE THE FACTS

MORE LIGHT

The Silver-spot and Silver-dot units using 100W—A-21 silvered bowl lamps produce higher lighting levels than all other types of recessed equipment using equivalent wattage. The Silver-spot unit develops nearly twice the candlepower of the 150W or projector lamp.

LOWER COST

Considering future lamp replacement and energy cost, the savings afforded by using Silver-spot and Silver-dot units will often pay for the equipment itself within 5000 hours of use of the unit.

EASIEST RELAMPING

Silver-spot and Silver-dot units use the compact 100W—A-21 silvered bowl lamp. They are designed so that lamps may be replaced either by hand or by using pole type vacuum operated lamp changers, without removing any fixture parts. No louvers, shields, glass or lenses to handle—no parts to get lost.

HIGHER MAINTAINED EFFICIENCY

The silvered bowl lamp with a sealed silver reflector is the heart of the Silver-spot and Silver-dot optical system. Each time a new lamp is installed the unit is restored to initial efficiency.

BETTER BRIGHTNESS CONTROL

In the Silver-spot and Silver-dot units the lamp filament is completely shielded by the silver process. The reflector is shielded by the fixture design to at least 45°. This means that these units can be used effectively in any area without glare or discomfort.

SKYLIKE Lighting, Inc. **104 West Main St., Bound Brook, N. J.**

Gentlemen:

Please send complete details on Silver-spot and Silver-dot

NAME_____

FIRM_____ TITLE_____

ADDRESS_____

CITY_____ ZONE_____ STATE_____

Silver-spot units may be recessed or surface mounted. Both Silver-spot and Silver-dot recessed units are furnished complete with plaster rings.

Each unit sold complete with two 100W—A-21 silvered bowl lamps.

SKYLIKE LIGHTING, INC.

RKO BLDG., RADIO CITY

NEW YORK 20, N. Y.

Now's The Time!

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Haddon Hall, ATLANTIC CITY, N.J.

September 13-17, 1954

Set your sights and sail for Atlantic City next September! The Philadelphia Section of I.E.S. is arranging the biggest and best National Conference in all I.E.S. history. Here's just a general idea of what's in store for you—

MEETINGS ... crammed with valuable information

SOCIAL EVENTS ... packed with fun

SPORTS ... bathing, boating, golf, fishing, races

SPECIAL PROGRAM ... for the ladies

SPACIOUS HOTEL ... luxurious living

DIAMOND JUBILEE ... electrical industry's celebration

CENTENNIAL ... celebrating Atlantic City's 100th birthday

TRANSPORTATION ... convenient plane, railroad and bus routes

VACATION ... ideal spot to spend family vacations

thousands already using it to help Plan Better Industrial Lighting...

HELPS PLAN

Thousands of architects are using it to help them plan the type and kind of lighting systems which will best fit the particular industrial building they are designing. They also use it to show their clients the reasons why the recommendations call for RLM-certified units.

HELPS BUY

It gives buyers by the thousands, such as industrial executives, operating chiefs or plant maintenance heads, dollars-and-cents reasons why RLM-labeled lighting units are the best buy in terms of quality, performance and sustained high lighting efficiency.

here's how this new "Blue-Cover" RLM SPECIFICATIONS BOOK is already helping thousands:

HELPS SELL

It enables thousands of electrical contractors, electrical wholesalers, etc. to point out to their customers EXACTLY WHAT THEY ARE GETTING for their lighting dollar. It shows why the RLM Label on a lighting unit takes the place of over 1,500 words of specifications!

HELPS RECOMMEND

To thousands of purchasing agents it serves as a valuable yardstick in their evaluation of industrial lighting ... an accurate guide to sound recommendations based on a comparison of the merits of different lighting units. It tells them what to look for and how to estimate lighting equipment value.

HELPS SPECIFY

To thousands of lighting men whose job it is to specify lighting units, it puts at their fingertips *21* different RLM Specifications, many complete with light distribution curves and coefficient of utilization tables. All are ready-made for use when drawing up lighting plans, layouts or recommendations.

This newly-revised "Blue-Cover" edition of the RLM Specifications Book of Industrial Lighting Units has just been made available to everyone who buys, sells and specifies industrial lighting equipment. Already thousands of copies have been requested and put to productive use in the planning of better industrial lighting.

NEW "UPWARD LIGHT" UNITS

In case you have not yet sent for your copy, be sure to do so before the supply is exhausted. This latest "Blue-Cover" edition of the RLM Specifications Book has been expanded to 52 pages, covering over 83 sizes and types of RLM-certified industrial lighting units. Featured are new specifications which embrace 15 variations of three new "Upward Component" RLM Semi-Direct Fluorescent Units which direct from 20% to 30% of the light upward. Also incorporated are important revisions and clarifications of existing specifications including new tables of typical coefficients of utilization and lighting distribution curves.

A request on your letterhead will bring your copy of this new RLM Specifications Book, as well as the pocket-size "RLM Questions and Answers" booklet, by return mail, without cost or obligation. Send now for this invaluable reference work to help you plan better industrial lighting!

RLM Standards Institute, Suite 823, 326 West Madison Street, Chicago 6, Illinois.

#R-352

RLM

ELECTRICAL TESTING LABORATORIES, INC.

RLM STANDARDS INSTITUTE

INCORPORATED

The letters RLM stand for Reflector and Lighting Equipment Manufacturers

FORD MOTOR CAR AND AIRCRAFT ASSEMBLY PLANT, CLAYCOMO, MO.

Largest post-war installation of its kind . . . uses

ELECTRO SILV-A-KING LIGHTING *throughout!*

HIGH BAY INSTALLATION: 2 Lamp 75 Watt—96" Slimline RLM Fixtures with Turret Lampholders. Electro Silv-A-King No. SL4296P. Ceiling Height app. 50'; mounting height 40' 6" mounted on 10' centers—average distance between rows 9' 6". Ceilings and walls off-white.

LOW BAY INSTALLATION: 2 Lamp 75 Watt—96" Slimline RLM Fixtures with Turret Lampholders. No. SL4296P.

ADMINISTRATION AREA: 2 Lamp 75 Watt 96" "Skylouver" Slimline Fixtures, Electro Silv-A-King No. SL1125 with styrene louvers and 45° x 35° shielding. Provide 150 foot candle rating maintained.

KITCHEN: 2 Lamp 38 Watt—48" Slimline Troffer with Alba Glass. Electro Silv-A-King No. TSL4248-2G. Provides 35 maintained foot candles over all working areas.

There's enough light in this new, 1,250,000 sq. ft. plant to supply a city of more than 25,000 people! Throughout this modern plant high levels of illumination without shadow or glare (a maintained foot candle rating of 35 in the factory areas—35 to 150 in the administrative areas) stimulate employee efficiency in every type of operation.

Exclusive engineering design which drastically reduced installation man-hours on each of the thousands of units . . . and which minimizes the maintenance factor were additional considerations in the selection of Electro Silv-A-King.

All of these lighting advantages are yours when you specify or install Electro Silv-A-King fluorescent or incandescent lighting for indoor or outdoor use . . . as well as the benefits of a nation-wide network of lighting specialists. Two strategically located manufacturing and shipping centers also provide more rapid, more economical supply to any job site.

A new fully illustrated catalog, including complete construction, installation and engineering data, is available by writing direct to . . .

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ELECTRICAL CONTRACTORS:
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A joint venture of:
Evans Electric Construction Company, Kansas City, Mo.
Kelso-Burnett Electric Company, Chicago, Ill.

ELECTRICAL ENGINEER:
Giffels & Vallet, Detroit, Michigan

ELECTRO SILV-A-KING CORPORATION

2000 West Fulton Street, Chicago 12, Illinois • Fairfield and State Streets, Bridgeport 5, Conn.

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- 90% EFFICIENCY
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  35°— 25°, 35°— 45°, 45°— 45°
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  4, 6 & 8 FOOT UNITS

AND

"ZONE OF LIGHT" ILLUMINATION

WITH EASTERN'S NEW "4 Lamp N SERIES"

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- FLUORESCENT & SLIMLINE, 4, 6 and 8 FOOT UNITS

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PUBLICATIONS *of the*
ILLUMINATING ENGINEERING SOCIETY

These publications summarize the studies and conclusions of technical committees of the Illuminating Engineering Society over a period of years. They contain the latest available information about many aspects of the art and science of illumination and include details of application as well as lighting technique. Each publication listed here carries the authority and approval of the Society.

These Society publications are available in single copies for information and for lighting reference book shelves or in quantity for educational or other distribution. Each publication is numbered for ordering when using the coupon printed on the back of this page.

(Supersedes all lists prior to January, 1954.)

(1) I.E.S. LIGHTING HANDBOOK, Second Edition

LATEST! One volume, 987 pages. Published 1952. Complete revision of first edition includes basic information on all phases of lighting practice and technique, based upon recently developed standards. Contains 18 technical reference and application sections; complete appendices of information regularly used; 655 photos, drawings, lighting tables, charts; fully cross-indexed . . . over 4500 items. For use of lighting engineers and specialists, consultants, architects, designers . . . all who plan, install and manufacture lighting systems and equipment.

$8.00 per copy; $6.40 in lots of ten or more. Add 50c for shipment abroad. *I.E.S. Members are entitled to one copy of the Handbook at $5.50 unless previously ordered.*

I.E.S. RECOMMENDED LIGHTING PRACTICES

These booklets contain the latest official I.E.S. lighting recommendations; illustrated with charts and photographs.

(2) OFFICE LIGHTING Recommended Practice (1947)

(3) LIGHTING PRACTICES FOR STORES AND OTHER MERCHANDISING AREAS (1948)

(4) SCHOOL LIGHTING American Standard Practice (1948)

(5) LIBRARY LIGHTING Recommended Practice (1950)

(6) DAYLIGHTING Recommended Practice (1950)

(7) SPORTS LIGHTING Recommended Practice (1951)

(8) INDUSTRIAL LIGHTING American Standard Practice (1952)

(9) STREET AND HIGHWAY LIGHTING American Standard Practice (1953)

(10) SUPPLEMENTARY LIGHTING Recommended Practice (1953)

Booklets above available at 50 cents per copy or in quantity as follows: first 4 copies, 50c each; next 20, 25c each; all over 24 copies, 15c each.

(11) RESIDENCE LIGHTING Recommended Practice (1953)
$1 per copy; quantity prices upon request.

REPORTS ON LIGHTING IN INDUSTRY

Lighting recommendations based on recent studies (research, surveys of current practice, and experimental installations) of the I.E.S. Committee on Lighting Study Projects in Industry; completely illustrated. Contain analyses of seeing tasks; recommended quality and quantity of lighting; and suitable lighting methods and systems for both general and supplementary lighting.

(12) LIGHTING FOR WOOLEN AND WORSTED TEXTILE MILLS (1949)
Detailed treatment of lighting for opening and grading, carding, spinning, weaving, and perching. Data are also applicable to other types of textile mills.

(13) LIGHTING FOR MACHINING OF SMALL METAL PARTS (1949)
Analysis of factors affecting visibility of convex scales, steel rules, scribed marks, center-punch marks, concave specular surfaces, plane and convex surfaces; general shop lighting; and supplementary lighting for various measuring instruments, bench work, machine tools, and inspection of polished surfaces.

(14) LIGHTING FOR FLOUR MILLS (1949)
Close-up photos of visual tasks and levels and quality of illumination for roll, sifter and purifier floors; packing areas; and product control stations.

(15) LIGHTING FOR CANNERIES (1950)
Recommendations based on committee study and research on general supplementary artificial lighting and daylighting for tasks common to all types of canneries. Also treated are light sources and equipment suitable for installation in canneries; sanitation and safety; and adequate electrical wiring.

(16) LIGHTING FOR BAKERIES (1950)
Committee study report on baking industry; complete with photos and drawings of typical flood arrangements and lighting layouts; paint color for visual environment; use of daylighting; lighting levels for various departments; maintenance. Also use of ultraviolet.

(17) LIGHTING OF CENTRAL STATION PROPERTIES (1951)
In two parts, Control Rooms and Load Dispatch Rooms, this report covers many peculiar seeing problems which are not typical of work areas in general. Such factors are covered as glare; indicating lamps; size of scales and lettering; instrument illumination. Recommends lighting levels for all areas and effective designs.

(18) LIGHTING FOR STEEL MILLS, PART I: OPEN HEARTH (1952)
Photographs and text describe lighting necessary for variety of tasks in this major industrial process. Figures show flow diagram of operations involved. Analysis of seeing tasks and illumination recommendations given in tables.

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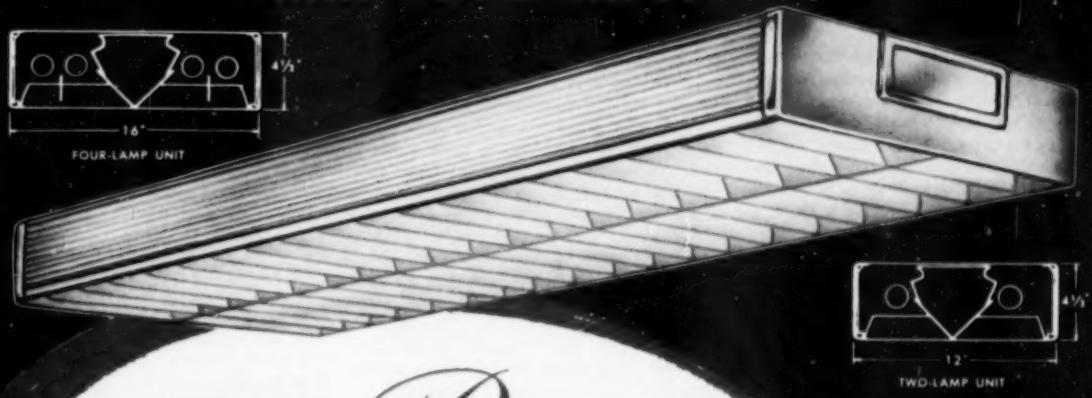

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1 Catalog of 34 pages describes company's complete line of fluorescent luminaires for a wide variety of commercial and industrial installations as well as for stock lighting and other special needs; gives complete illumination and installation data. Leadlight Fixture Company, Oakland, Calif.

2 Bulletin GEA-5965 covers all available time switches, process timers, and time meters made by company. Its 24 pages contain selection and application information as well as descriptions of various types and models. General Electric Co., Schenectady, N. Y.

3 Ceiling lighting systems booklet gives descriptions of 11 major types of lighting equipment with structural drawings and illumination data, including quick computation formulas for translucent ceilings; gives facts on acoustical effectiveness of baffles. F. W. Wakefield Brass Co., Vermilion, O.

4 Bulletin A-295 shows company's several new types of high intensity mercury vapor lamps for a number of different lighting purposes; table gives technical data and operating characteristics. A-305 describes reflector lamps; furnishes operating data. Amplex Corporation, Brooklyn, N. Y.

5 Two new folders describe company's Plymouth and Puritan lines of fluorescent luminaires designed for schools, stores, offices, banks and similar installations. Folders feature new socket holder bridge developed to improve flexibility of luminaire's use and give technical lighting data on each. Smitheraft Lighting Division, Chelsea, Mass.

6 Technical Data Bulletin 381-F shows methods and materials necessary for installing obstruction lighting equipment on radio, TV and microwave relay towers. 20-page booklet includes layout drawings with complete bills of materials for lighting towers of all heights. Crouse-Hinds Co., Syracuse, N. Y.

7 Folder tells of development of company's new PARA-LOUVER, a new fixture louver design said to reduce lengthwise brightness 50% without sacrifice of future efficiency. Story explains principles involved and methods of fabrication. Day-Brite Lighting, Inc., St. Louis, Mo.

8 Bulletin 83 covers new Hi-spot lamps especially designed for lighting indoor and outdoor areas from unusually great distances. Bulletin says that lamps can be used at higher mounting heights, and their narrow beam is said to provide uniform illumination of higher intensity than ordinary R40 lamps. Radiant Lamp Corp., Newark, N. J.

9 New Prescolite catalog of surface luminaires and portable lamps shows company's line of bullet-type reflectors in a wide variety of shapes and groupings for commercial and residential installation. Prescolite Mfg. Corp., Berkeley, Calif.

10 Catalog No. 82, fully illustrated, contains design photos, drawings, and other data covering standard lighting pole brackets, mast arms and accessories; includes detailed construction and mounting instructions for installation. Union Metal Mfg. Co., Canton, O.

11 Catalog sheet shows company's new Series 3400 incandescent luminaires for ceiling mounting; in five sizes from 8" to 16" diameters; gives lighting curves, coefficients of utilization and other data. Solar Light Mfg. Co., Chicago, Ill.

12 New booklet "Modern School Lighting" features variety of school lighting installations in which silvered bowl incandescent systems have been used, explaining as well some of the problems encountered in this field. Silvray Lighting Inc., New York, N. Y.

13 Attractive, 20-page, two-color booklet furnishes complete data on company's ballasts for fluorescent lamps; explains ballast circuits and construction; shows variety of types and gives installation and operation data. Advance Transformer Co., Chicago, Ill.

14 New recessed incandescent fixture with Strato-Ray lens said to reduce approach glare area is described in new four-page folder, giving construction details and explaining ease of maintenance and other features. Pryne and Co., Inc., Pomona, Calif.

15 New 14-page catalog contains complete specifications of Careo standard steel anchor base and transformer base poles and brackets; gives comprehensive picture of component parts and complete erection data. Pacific Car & Foundry Co., Seattle, Wash.

16 64-page Datalog gives general lighting information such as fundamentals of light control; recommended levels; design data; room index and coefficients of utilization, then describes company's complete line of commercial, institutional, and industrial luminaires, giving full technical data on each. Holophane Co. Inc., New York, N. Y.

17 Synctron electronic flash units for professional and amateur photography are covered in company's catalog, giving full details of special features and other data. Dormitzer Electric & Mfg. Co., Cambridge, Mass.

18 Bulletin 134 shows Dextra-Lites, universally adjustable portable lighting units for industrial and commercial applications; gives details of special spring-tension socket and swivel and construction data. Swivelier Co. Inc., Brooklyn, N. Y.

19 16-page brochure describes Mirne-O-Lite line of cold cathode fluorescent lighting equipment; gives light curves and other data on bent lamp group of fixtures; shows some typical installations, explains features of this type. Cutler Light Mfg. Co., Philadelphia, Pa.

20 Handbook of Lighting Glassware, 24 pages, gives basic types of lighting glassware, both for fluorescent and incandescent; recommends effective use to produce type of light desired, and integration into architecture; explains lighting calculations. Corning Glass Works, Corning, N. Y.

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21 New 8-page booklet gives complete engineering data and dimensions on company's new Peerlite line of air-cooled fluorescent fixtures. Provides photometric data and installation details. Edwin F. Guth Co., St. Louis, Mo.

22 Catalog Sheet No. 1020 illustrates and describes new Type B Time Switch, NEMA standard 30 amp, single-pole, steel-cased switch; gives many operating features. Sangamo Electric Co., Springfield, Ill.

23 16-page booklet designed to answer questions concerning the use of the plenum above luminous ceilings for heating and/or ventilating; gives details with graphs and illustrations on presure loss; flow pattern; heat transfer; plenum supply, and other material. Luminous Ceilings, Inc., Chicago, Ill.

24 Catalog sheet shows new horizontal fluorescent "T" light designed for outdoor use particularly in gas stations: shows versatility and adaptability to existing standards, and how clusters may be adapted with it. Guardian Light Co., Oak Park, Ill.

25 Catalog No. 52 contains company's entire line of fluorescent luminaires for many types of commercial, institutional and industrial installations; gives photometric and installation data, as well as showing some typical jobs. Ruby Lighting Corp., Los Angeles, Calif.

(*Continued from page 15A*)

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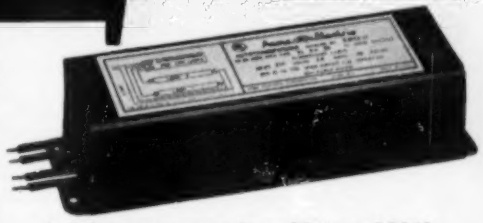

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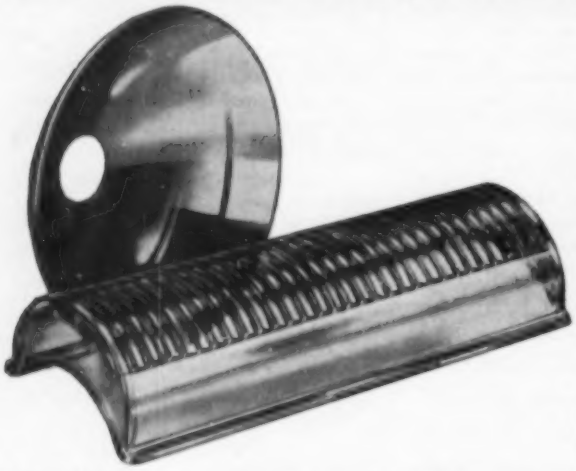

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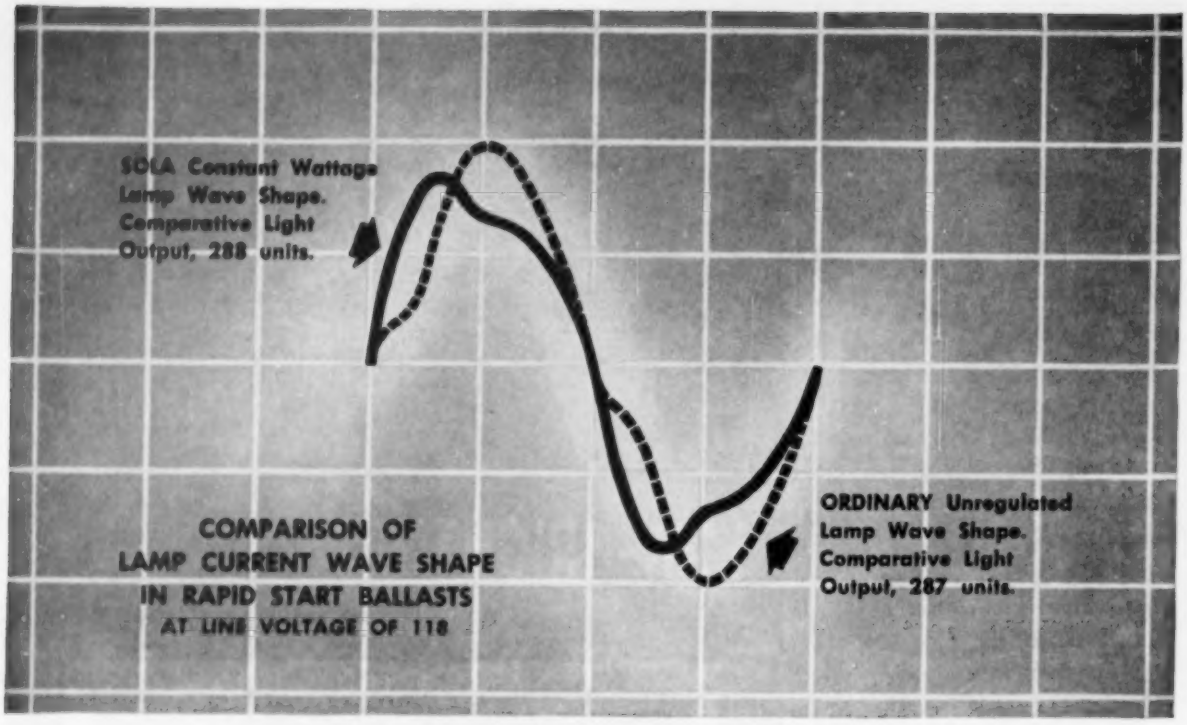
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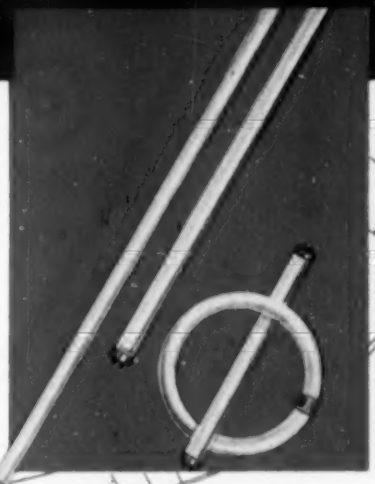

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QUIET, TROUBLE-FREE OPERATION

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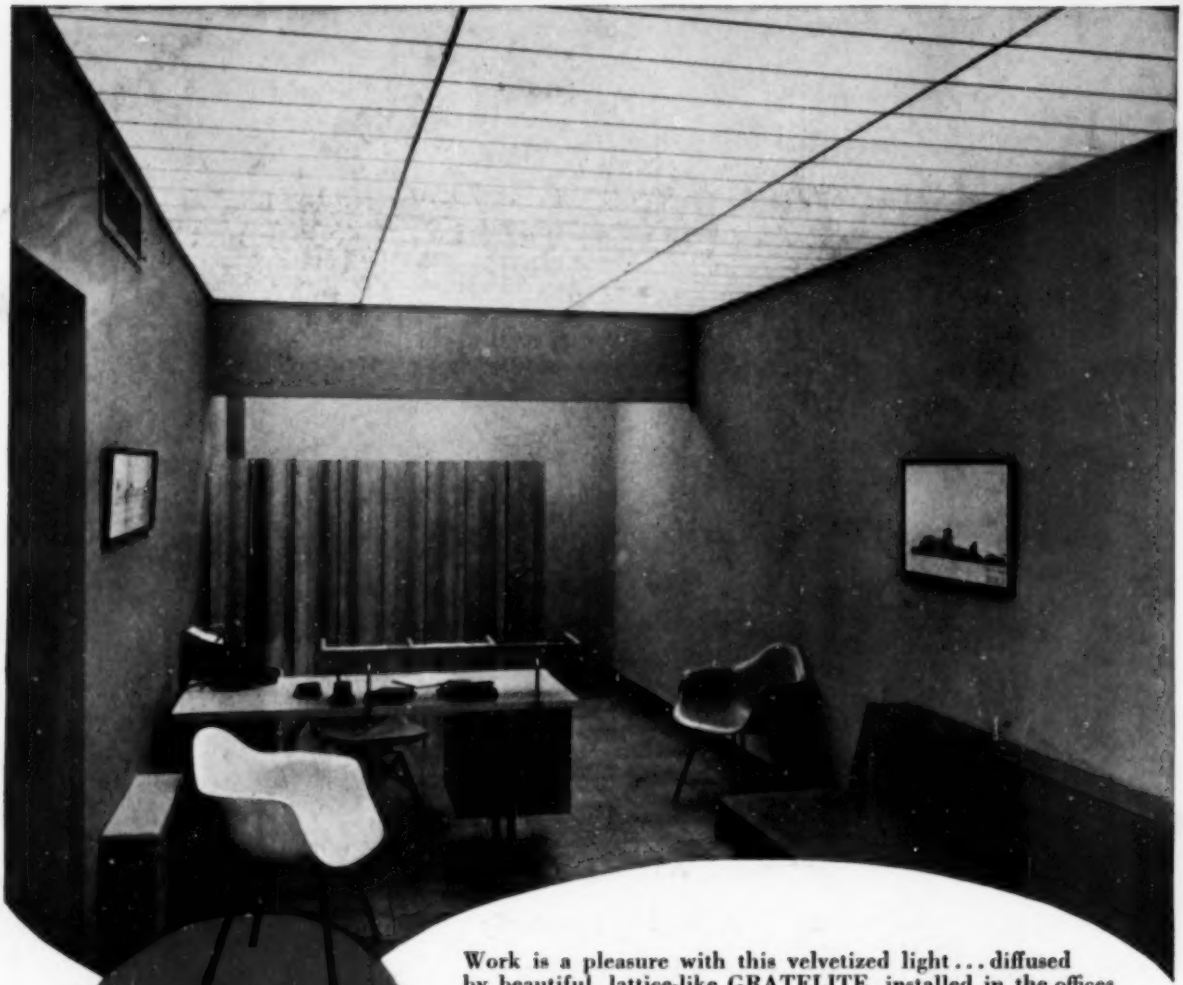
**Nine leading manufacturers make CBM CERTIFIED BALLASTS.*

2116 KEITH BLDG., CLEVELAND 15, OHIO



work-inspiring lighting created by GUTH* GRATELITE CEILINGS

*U. S. & Foreign Trademarks

Guth

Work is a pleasure with this velvetized light... diffused by beautiful, lattice-like GRATELITE, installed in the offices of MacKenzie, Knuth & Klein, Architects of Flint, Michigan.

data:

Room Size: 23'4" x 9'10" x 10'9"

Luminaires: Guth Super-Strips
12 96" T-12 Lamps, 4500° White
Mounted on 24" Centers, 10'6" high

GRATELITE Ceiling: Mounted 8'6" above floor

Foot-Candles: All Super-Strips on—86 F. C.
One-Half Super-Strips on—42 F. C.

	BRIGHTNESS READINGS:	FOOT LAMBERTS	C.P./SQ. IN.
1.	*GRATELITE Ceiling at approx. 30° Angle*	120	.260
2.	*East Wall (French Gray)*	20	.046
	Dado	13	.028
3.	*South Wall (Deep Coral)*	9½	.021
4.	*Floor (Natural Cork Tile)*	17½	.038
5.	*Desk (Chartreuse)*	36	.080

Just think: 86 Foot-Candles—and yet only 120 Foot Lambert Brightness! Never before was such low brightness with such high illumination values thought possible. Make this dream come true for you. Write on your letterhead for Catalog 905-I and GrateLite layout guide.

THE EDWIN F. GUTH COMPANY ST. LOUIS 3, MO.

Leaders in Lighting since 1902